ACTA UNIVERSITATIS SZEGEDIENSIS

PARS CLIMATOLOGICA SCIENTIARUM NATURALIUM

CURAT: ILONA BÁRÁNY-KEVEI

ACTA CLIMATOLOGICA

TOMUS XXXI/A

SZEGED, (HUNGARIA)

1997

ACTA UNIVERSITATIS SZEGEDIENSIS

PARS CLIMATOLOGICA SCIENTIARUM NATURALIUM

CURAT: ILONA BÁRÁNY-KEVEI

ACTA CLIMATOLOGICA

TOMUS XXXI/A

SZEGED, (HUNGARIA)

1997

Editor

DR. ILONA BÁRÁNY-KEVEI

Technical editors

LAJOS CSIKÁSZ
DR. JÁNOS UNGER

Publisher
József Attila University, Faculty of Sciences
(H-6720 Szeged, Aradi vértanúk tere 1.)

ISSN 0563-0614

CONTENTS

ACTA CLIMATOLOGICA
Universitatis Szegediensis, Tom. 31B, 1998, 3-6.

CLIMATE AND AIR HYGIENE INVESTIGATIONS FOR URBAN PLANNING

W. KUTTLER

Institute for Ecology, University of Essen, 45 117 Essen, Germany

Összefoglalás - A tanulmány az alkalmazott városklimatológia bizonyos aspektusaival foglalkozik, majd a tudományág feladatainak, céljainak leírása után különböző vizsgálati módszereket mutat be. A továbbiakban a hőmérsékleti és levegő higéniás értékek mobil mérésére összpontosít és a levegő higéniás helyzetek szintetikus klíma-funkciós térképek segítségével történő bemutatását és kiértékelését tárgyalja.

Summary - This paper deals with certain aspects of applied urban climatology. Following a description of the objectives of this branch of science, various investigation methods are presented. The paper concentrates on the use of mobile measurements of temperature and air hygiene values and concludes with a discussion of the possibilities of presenting and evaluating air hygiene situations using synthetic climate function maps.

Key words: urban climate, mobile measurements, synthetic climate function maps

1. INTRODUCTION

The microclimatic and mesoclimatic features which distinguish cities from their environment are caused by a number of factors. These include the conversion of the natural ground surface into a three-dimensional space consisting largely of artificial materials, the resulting reduction in the proportion of the surface covered by vegetation and the impact of industrial processes, causing waste heat, waste gases, dust and soot.

The climatic and air hygiene features characterizing conurbations are normally referred to as "urban climate" (*Landsberg*, 1981). They can be observed both in small towns and in large cities (*Unger*, 1996). The factors mentioned above affect the radiation and energy balance of near-surface layers of the atmosphere, the possibilities of evaporation and the wind field to such an extent that urban areas are generally characterized by higher air temperatures, lower relative humidities, poorer ventilation and accumulations of particulate and gaseous contaminants (*Kuttler*, 1997). These features of urban climate can be modified both by small-scale factors such as relief and by the location of cities at different latitudes.

2. APPLIED URBAN CLIMATOLOGY

Applied urban climatology (*Kuttler,* 1996) is the science concerned with investigating aspects of urban climates relevant to planning purposes. The tasks of applied urban climatology include the analysis, evaluation and modelling of existing conditions, and, to an ever increasing extent, planned situations. The purpose of such investigations is to give decision-makers in cities and communities the guidelines they need as a basis for land utilization recommendations. In order to solve these problems, which are by no means always simple, a wide range of measurement and analysis tools are now available for use when the need arises.

3. INVESTIGATION METHODS

Various techniques are used for urban climate investigations depending on the question in hand. These include field measurements, mathematical modelling, infrared image analysis and wind tunnel tests. This article briefly discusses the problems of field measurements.

Both stationary and mobile measurement stations are used to gather data on relevant climate elements such as dry and wet air temperatures, radiation components and air quality with as effective a coverage of the area as possible.

As the effects of urban climates are especially pronounced in meteorological situations characterized by low wind and high radiation, measurements are mainly made in such conditions. The main emphasis in urban climate studies is on recording the thermal behaviour of the city body and the resulting distribution of air temperatures, on investigation air composition in terms of the quality and quantity of trace substances and finding evidence for local wind systems. Such wind systems may arise as a result of the temperature differences between open and built-up areas and are referred to as country breezes (*Barlag and Kuttler,* 1990/91). In an ideal case, these near-surface air movements, mainly intermittent and of low velocity, can be observed to flow towards the centre of the city centripetrally from all directions. The depth of penetration into the urban area also depends on the ventilation channels available. The quality of the air carried into the city from its surroundings is also a function of any prior contamination with pollutants. Normally, investigations of these aspects are conducted over a period of at least one year using networks of special stations in areas of special climatic and air hygiene importance. However, it must be remembered that even data gathered from such special networks initially only give an indication of conditions at the actual station sites. It is still necessary to evaluate these data in order to establish a connection to an area. Fixed-station measurements can be related to areas using a mobile measurement laboratory, normally a laboratory van. *Fig. 1* shows a vehicle of this type operated by the Institute for Ecology of Essen University, Germany. With the aid of this vehicle, it is possible to

Fig. 1 The mobile measurement laboratory van in action

measure important climatological and air hygiene parameters within a closely meshed network almost simultaneously. High-density data gathering produces results which allow for a well-founded interpretation.

In this case, air temperatures and humidity are measured, together with concentrations of various substances (NO, NO_2, CO, O_3) on predetermined routes during the test trip. In the case of longer test trips through large cities, it may be necessary to make some chronological corrections to the data collected as time differences between the measurements may otherwise distort the results. With the methods available, data corrected to one reference time form the basis for an area-wide assessment. The measurement results obtained can be used for generating synthetic climate function maps and for planning guideline maps based on them.

4. SYNTHETIC CLIMATE FUNCTION MAPS AND PLANNING GUIDELINE MAPS

Applied urban climate studies are based on a large volume of data which must be processed in such a way that they can be used for planning purposes. Maps are an important tool in this respect as they are of considerable practical use to planners and allow the presentation of climatological and air hygiene data over an area (*Barlag*, 1993). Synthetic climate function maps and planning guideline maps based on them create a spatial frame of reference for climatological and air hygiene values. These maps not only interconnect the individual data and present them in a more or less generalized form depending on the scale of the map but also contain assessments of bioclimatological and air hygiene values. In this way, it is possible to distinguish areas which are favourable and unfavourable in terms of climatic conditions. Following the performance of the investigations required, maps of this type can be prepared for any urban area and are an important tool not only for basic research work but also for urban planning decisions.

In the near future, it is expected that there will be an increasing demand for data of this type by urban planning authorities aiming for sustainable urban development with conservation of resources, especially in connection with the application of environmental impact studies. For this purpose, intensive cooperation and basic research work will be needed, especially with a view to developing standardized measurement methods for use throughout Europe. Initial contacts with some climatological institutes in other European countries have already been established. Work on the establishment of further contacts is in progress.

REFERENCES

Barlag, A.-B., 1993: Planungsrelevante Klimaanalyse einer Industriestadt in Tallage. *Essener Ökologische Schriften 1*, Westarp-Wissenschaften, Essen.

Barlag, A.-B. and W. Kuttler, W., 1990/91: The significance of country breezes for urban planning. *Energy and Buildings 15-16*, 291-297.

Kuttler, W., 1996: Aspekte der Angewandten Stadtklimatologie. *Geowissenschaften 14*, 221-228.

Kuttler, W., 1997: *Städtische Klimamodifikation. VDI-Berichte 1330 (Umwelt- und Klimabeeinflussung durch den Menschen IV)*, 87-108.

Landsberg, H.E., 1981: *The Urban Climate*. International Geophysics Series, Vol. 28, New York.

Unger, J., 1996: Heat Island Intensity with different meteorological conditions in a medium sized town: Szeged, Hungary. *Theor. Appl. Climatol. 54*, 147-151.

ACTA CLIMATOLOGICA
Universitatis Szegediensis, Tom. 31A, 1998, 7-15.

THE CARBON CYCLE IN THE EARTH-ATMOSPHERE SYSTEM AND THE CLIMATE CHANGE

GY. KOPPÁNY

Department of Climatology and Landscape Ecology, József Attila University, P.O.Box 653, 6701 Szeged, Hungary

Összefoglalás - Az IPCC modellekkel végzett kísérletek alapján a légkör CO_2 koncentrációja 40-240 év múlva stabilizálható 450-1000 ppmv szinten a CO_2 emisszió megfelelő korlátozásával. Kérdés, hogy mennyi ideig áll rendelkezésre fosszilis tüzelőanyag. A szén körforgalma a Föld-légkör rendszerben irreverzibilisnek tűnik: nem valószínű, hogy a fanerozoikum maximális CO_2 koncentrációja megismétlődik. A földkorongra évente érkező napsugárzás energiájának néhány ezreléke, esetleg egy százaléka kémiai energia formájában raktározódik a bioszférában. Ennek egy töredéke megközelíti az emberiség évi energia fogyasztását. Az energia problémának másik megoldása a takarékosabb technológiák bevezetése. A CO_2 koncentráció növekedését a növényzet növekvő intenzitású fotoszintézissel is mérsékelheti.

Summary - According to IPCC model experiments the atmospheric CO_2 concentration could be stabilized at 450-1000 ppmv levels in 40-240 years depending on restriction measures of CO_2 emission. However the amount of available fossil fuels is rather uncertain. The carbon cycle in Earth-atmosphere system seems irreversible: it is unlikely that the maximum CO_2 concentration of Phanerozoic will return. A portion (a few thousandths or one percent) of solar energy reaching annually the Earth's surface is accumulated in biosphere as chemical energy. Its few percents may approximate the annual energy consumption of mankind. Another solution to energy problems could be found in use of more economic technologies. The response of plants to increasing CO_2 concentration in enhanced photosynthesis which may moderate CO_2 increase in the atmosphere.

Key words: consumption of carbonaceous fuels, variations of CO_2 in Phanerozoic, carbon cycle, chemical energy, biosphere

INTRODUCTION

The climate of the 21st or 22nd centuries depends largely upon the atmospheric concentration of greenhouse gases. Without atmosphere (and greenhouse effect) the mean global surface temperature would be about 255 K (-18°C). In fact the mean global surface temperature is 288 K (15°C), that is the actual surface temperature is about 33 K higher than it would be expected in case of simple radiation equilibrium. According to some estimation, 62% of greenhouse effect may be attributed to water vapour, 22% to CO_2, and 16% to other gases (e.g. CH_4, O_3, N_2O, CFC-s, etc.) (*Schönwiese*, 1995). It means that the most important greenhouse gas affected by human activity is CO_2.

The theoretical calculations concerning the possible change in climate are based on assumption of continuos increase in atmospheric CO_2. If the growth rate of CO_2 concentration will be as much as in years 1984-93, then the doubling will happen within 160 years. However, after taking into consideration some resrictions in CO_2 emissions, we may get conclusions, as follows (*Climate Change*, 1995):

if the CO_2 emissions drop to 1990 levels, respectively, cca 40, 140, 240 years from now, then

duration of restriction in years	*ppmv*	*mass of C in kg*	*mass of CO_2 in kg*
present (1995)	358	$5x10^{14}$	$1,86x10^{15}$
40	450	$6.3x10^{14}$	$2.31x10^{15}$
140	650	$10.3x10^{14}$	$3.78x10^{15}$
240	1000	$14.1x10^{14}$	$5.17x10^{15}$

IPCC (1994) carbon cycle models were used to calculate the emissions of CO_2, which would lead to stabilisation at a number of different concentration levels from 450 to 750 ppmv. If global CO_2 emmisions were maintained at near current (1994) levels, they would lead to a nearly constant rate of increase in atmospheric concentration for at least two centuries reaching about 600 ppmv by the end of the 21st century.

However the crucial point is whether the consumption of carbonaceous fuels could remain at present levels for two centuries. The assessment of traditional energy sources is uncertain, but the increase of their cost is doubtless. Thus the questions to be answered are: how long can we use traditional energies taken from fossil fuels, and how can they be replaced with other energy sources.

In order to approach the solution of problems, mentioned above, first we shall give a rough survey of variations of atmospheric CO_2 concentration during the Phanerozoic and the carbon cycle in the Earth-atmosphere system, second we try to assess the energy amounts accumulating in biosphere yearly from solar radiation and its portion available for mankind.

It is noteworthy to mention that the largest environment change in Earth-atmosphere system took place about 700 million years ago after appearance of free oxygen in the atmosphere (*Lukács*, 1994)

VARIATIONS OF ATMOSPHERIC CO_2 CONCENTRATION AND GLOBAL TEMPERATURE IN PHANEROZOIC

The composition of terrestrial atmosphere and the global mean temperature can be reconstructed relatively well, making use of paleoclimatogal, mineralogical, paleontological data from the last 570 million year period (*Budyko*, 1982; *Budyko et al.*, 1987, 1988). Temporally weighted mean mass of the atmospheric CO_2 in Phanerozoic has been as much as

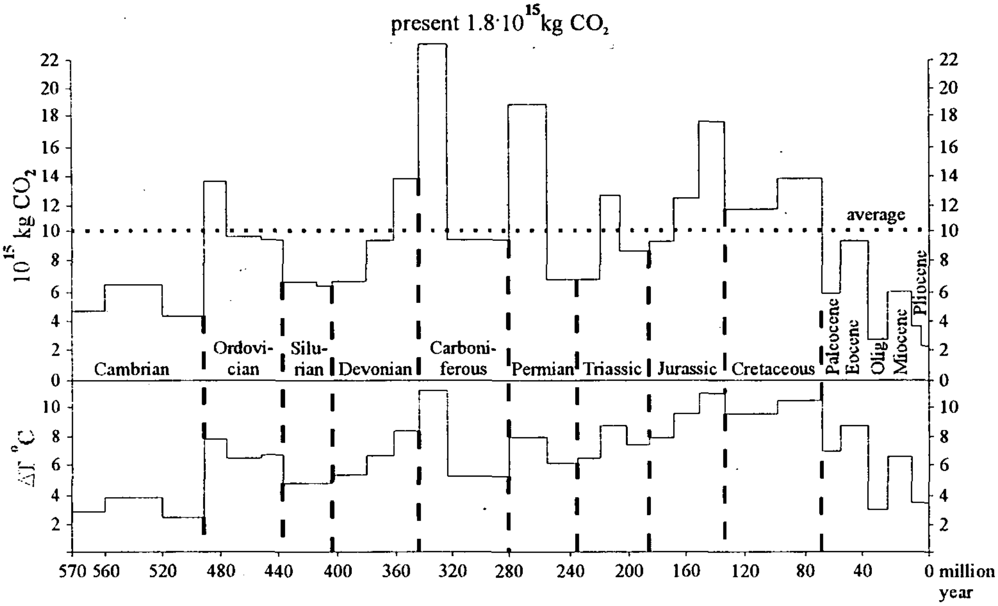

Fig. 1 Variations in mass of atmospheric carbon-dioxide (above) and global surface temprature deviation from presents value (below) during Phanerozoic

10^{16} kg, i.e. 5.5 times more than present value (PAL = Present Atmospheric Level: 1.8×10^{14} kg). In early Carboniferous it reached the maximum concentration which is about 12 times larger than PAL. Other maxima were found in early Permian, late Jurassic and late Cretaceous (*Fig. 1*). However in the last 70 million years the atmospheric CO_2 amount did never exceed the average value (10^{16} kg), moreover it has been gradually decreasing until the Holocene time.

It is noteworthy that the estimated mean global temperature varies more or less parallel with CO_2 concentration. An approximative relationship can be established between the atmospheric CO_2 mass and global mean temperature, namely:

$$\Delta T = 2.5 \times b \qquad (K) \qquad (1)$$

here b = log k/log2, if k > 1, and denotes the ratio between past and present CO_2 amounts in the atmosphere, so "b" is the number of doubling in CO_2 mass: $\Delta T > 0$ stands for increase of global mean temperature in comparison with the present value (e.g. in *Table 1*).

Table 1 Temperature deviations in several earth historical periods (legends see in the text)

	k	*b*	*ΔT gained from (1)*	*ΔT estimated (see Fig. 1. below)*
early Carboniferous	12.7	3.67	9.2 K	11 K
early Permian	11.1	3.47	8.6 K	8 K
late Jurassic	9.9	3.3	8.2 K	10.9 K
late Cretaceous	7.6	2.93	7.3 K	10.4 K
early Cambrian	2.7	1.44	3.6 K	2.9 K
early Ordovician	7.5	2.9	7.3 K	7.7 K
late Silurian	3.67	1.87	4.7 K	4.8 K

The decrease of atmospheric CO_2 has been accompanied by dropping in global temperature in the last epoch of Earth's history (*Fig. 1,* below). The temporally weighted average of global temperature during the Phanerozoic was about by 6°C higher than at present.

Consequently it may be stated that the present CO_2 concentration and global mean temperature exhibit peculiar stage of the atmosphere*. So we shall investigate the possible causes of this extreme atmospheric stage, namely the low CO_2 concentration, and we shall thoroughly discuss the problem: whether human activity is able to release as much CO_2 into the atmosphere to reach the mean value of Phanerozoic?

Recently a great number of papers is concerned with the carbon cycle in the Earth-atmosphere system (*Bernáth et al.*, 1981; *Houghton*, 1996; *Lassey et al.*, 1996). For the sake of a good survey, here a very simplified sketch is presented on the carbon cycle (*Fig. 2*), e.g. no

* The data involved in *Fig. 1* are valid only in 10 million year periods and exclude those in shorter episodes like glacials or interglacials.

distinctions are made between carbon budget in shelves, in surface oceans, and in deep ocean, respectively. It is a much-debated question, whether the CO_2 mass infiltrated annually into biomass from the atmosphere and CO_2 mass released yearly from biosphere due to decomposition are comparable to each other. The most recent calculations suggest that the latter is less with an order of magnitude than the former (*Houghton*, 1996; *Lassey*, 1996). Therefore the arrow is directed from atmosphere to the biosphere in *Fig. 2* and not vice versa. The biomass contains 8×10^{14} kg C, in the soil the estimated mass of organic carbon (like peat, humus, marsh gases etc.) is 2×10^{15} kg. Mass of carbonates in minerals, rocks and fossils is as much as 5×10^{20} kg, that is nearly ten thousandth of the total mass of Earth (6×10^{24}). Another transport takes place through the oceans, both in form of carbon exchange between the atmosphere and oceans, and between the oceans and biosphere, respectively. In oceans 1.3×10^{17} kg CO_2 is dissolved, which is the source of organic carbons for living creatures in water.

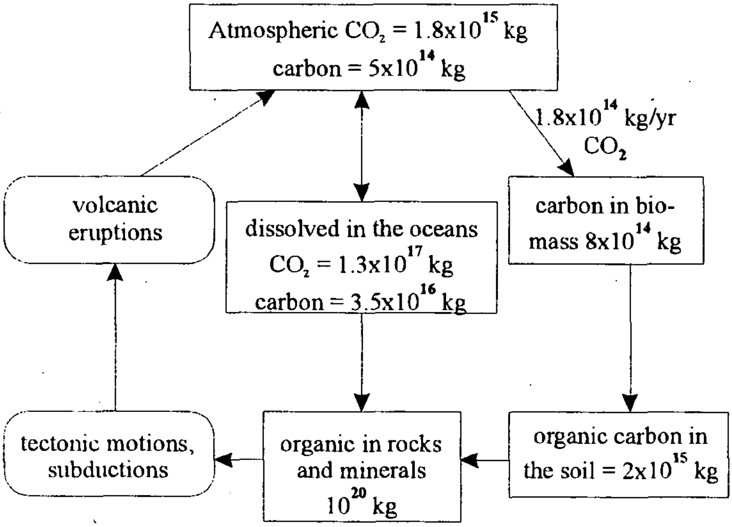

Fig. 2 Carbon cycle in Earth-atmosphere system

Due to subductions some carbonates sink deep into the mantle of the Earth, warming up by several 100 K. The carbonates however can not catch CO_2 above cca 350°C, so the latter will be released, and more or less portion of it may be transported into the atmosphere mostly by volcanic eruptions.

It is rather questionable how much fossil fuel may be used from the litosphere, but no doubt will remain about the increase of its price. In 1973 e.g. the price of a barrel of oil increased from 4 USD to 11.7 USD, and this fact caused dramatic consequences in countries, whose developed industry has been maintained by imported energy sources, like Japan. Recent price of a barrel of oil varies about 20 USD. Similar could be stated about hard coal and natural gases.

It is quite sure that mankind will not reduce energy consumption in the near future. Therefore we have to find some solutions for our energy problems. In this paper we shall present two possible solutions, one active and one passive possibilities. The first is the harnessing of chemical energy accumulated annually from solar energy in biosphere. The second is the reduction of waste in energy consumption.

HARNESSING OF CHEMICAL ENERGY ACCUMULATED ANNUALLY FROM SOLAR ENERGY IN BIOSPHERE

The annual radiation absorbed in the Earth-atmosphere system is as much as 3.86×10^{24} J/year (with 0.3 albedo). The estimated amount of chemical energy accumulated yearly in biosphere from solar energy ranges from about 6×10^{21} to 4×10^{22} J/year, i.e. cca 0.15-1% of solar energy.

The annual energy consumptions of mankind were in recent years as follows:
1980: 3×10^{20} J; 1985: 3.3×10^{20} J; 1995: 5×10^{20} J.

Hence the world 1995 energy consumption is 1-8% of chemical energy gained yearly from solar radiation in biosphere. Supposing 20% efficiency, there would be needed to use roughly 6-20% chemical energy accumulated yearly in biosphere in order to satisfy the energy consumption of mankind, or at least a great part of it.

In the light of these theoretical calculations we ought to consider some practical realizations concerning the energy transformation. Carbohydrates can be transformed into alcohol, which is a high quality fuel. During the World War 2 and a couple of years after it, artificial gasoline was used in a few European countries. There are biogas producting plants offering energy from biomass, too.

In some of developed countries there is significant surplus in production of cereals and provisions. The governments of these countries urge the farmers to leave unutilized parts of their fields. These uncultivated fields might be used for growing industrial plants like sugar-beet, sugar broomcorn, potato etc. Each provides some kind of carbohydrates, basic chemical material of alcohol manufacturing (*Hunkár*, 1996).

ECONOMY IN CONSUMPTION OF ENERGY

In the late 19th and early 20th centuries, when introduction and general use of engines took place, like steam-engine, steamer, locomotives, heat-engines, motorvehicles, aircrafts, wide-spread use of electricity, in the beginning the energy was cheap and the quantity of energy use increased rapidly. The use of electricity in households has become more and more common, transport replaced animal and human powers gradually with mechanical vehicles. In 1860 the world energy use was supplied by animal power in 73%, by human force in 15% and the residual 12% was gained from other sources (wind, hydraulic power, steam-engine etc.) (*Sabady*, 1980). Nowadays in a developed industrial country the per capita use of energy is approximately equal to 200-500 slave power or 20-50 draught animal force (*Koppány*, 1989).

The largest energy consumer is industry. It is evident that the common requirement of mankind is to rise the standard of life, and consequently the energy consumption must be increased. Certainly it will be the case in less developed countries, e.g. in Africa, Latin America and a few countries in Asia. However, sooner or later, the use of fossil energy sources must be restricted, mostly for the permanent rise of their prices.

The change in specific energy consumption of some industrial countries indicates that the economy in this field started in the late 19th or during the first half of the 20th century. The term of specific energy consumption here denotes energy use per 1000 USD GPD. *Fig. 3* presents the variation of specific energy consumption (in ton oil equivalent unit) in a few developed countries since the second half of the 19th century up to the latest available or predictable time. It is noteworthy that by the 1980s the specific energy consumptions are rather close to each other in presented countries. This suggests that a rather similar economical energy use has been introduced in developed countries. With comparison: specific

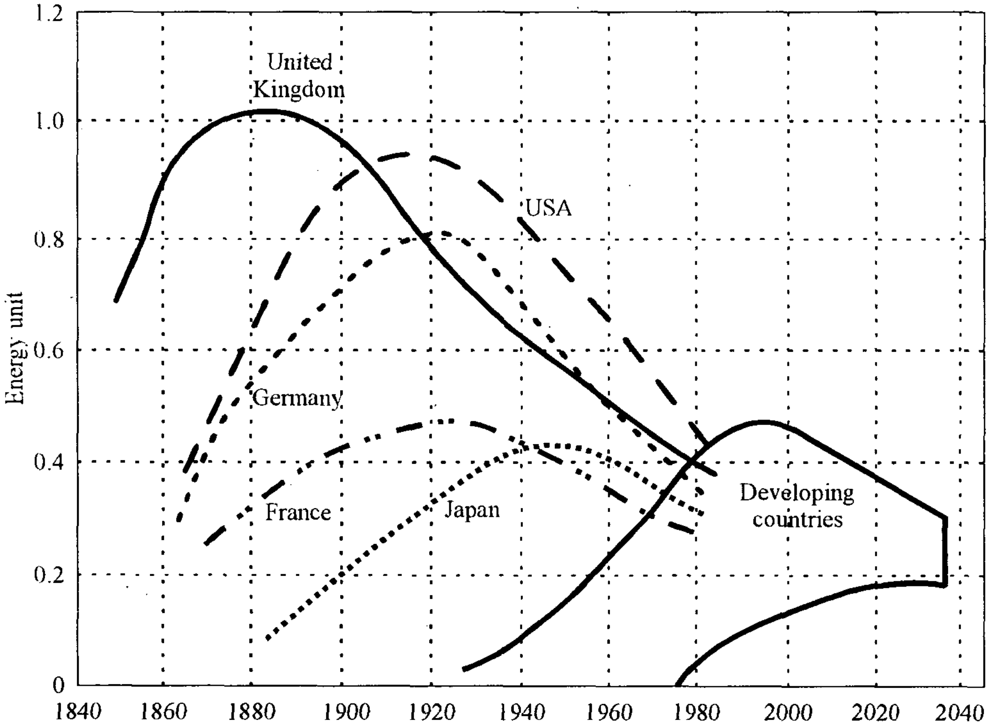

Fig. 3 Changes in specific energy consumption (energy use per 1000 USD GDP energy in ton oil equivalent unit) since middle of the 19th century

consumption in Hungary in late 1980s was about 2-3 times larger than that in West Germany. Thus in Hungary and some other Eastern-European countries one of the main tasks is to reduce the waste of energy use by introducing more economical techniques.

THE RESPONSE OF PLANTS TO INCREASE OF ATMOSPHERIC CO_2 CONCENTRATION

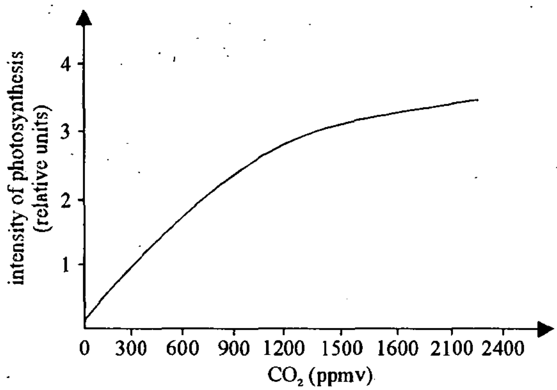

Fig. 4 The change of intensity of photosynthesis of Scotch pine depending on carbon-dioxide concentration

By 1995 it was found that the growth rate of atmospheric CO_2 concentration exhibited a small decrease during the 1985-94 decade (*Climate of Europe*, 1995; *Climate Change*, 1995), the decrease took place mostly in 1991-93. The change was observed among others at Izana. The most likely explanation of slackening in growth rate of CO_2 concentration is the response of plants to increase of CO_2 concentration. A series of biological experiments in laboratories show unanimously the reaction of plants to the change of CO_2 concentration. If sufficient solar radiation is available, the intensity of photosynthesis will grow with growing CO_2 concentration up to 2400-3000 ppmv, e.i. about to amount 8-10 times than PAL (*Fig. 4*).

Although the slackening of growth rate in CO_2 concentration may be a transitional phenomenon and must not be extrapolated to the long-term future, it proves that the change in the composition of atmosphere is influenced by many factors besides the human activity.

REFERENCES

Barry, R. G. and Chorly, R. J., 1982: *Atmosphere, Weather and Climate.* Methuens.

Bernáth, J. et al., 1981: *Biogeography, coenology, ecology (in Hungarian).* Lecture notes, Tankönyvkiadó, Budapest.

Budyko, M. I., 1982: *The Earth's Climate: Past and Future.* Academic Press Inc. International Geophysics Series Vol. 29.

Budyko, M. I., Ronov, A. B. and Yanshin, A. L., 1987: History of the Earth's Atmosphere. Springer Verlag.

Budyko, M. I., Golitsyn, G. S. and Izrael, Y. A., 1988: *Global Climatic Catastrophes*. Springer Verlag.

Climate Change 1995. The Science of Climate Change. Tech. Summ. of Working Group I. WMO UNEP, adapted by IPCC.

Climate of Europe. European Climate Support Network, 1995.

Houghton, R. A., 1996. Terrestrian sources and sinks of carbon inferred from terrestrial data. *Tellus 48 B*, 420-432.

Hunkár, M., 1996: Renewable resources - biomass - sugar broomcorn (in Hungarian). *Légkör 41, No. 4*, 15-17.

Koppány, Gy., 1989: *Atmospheric resources (in Hungarian)*. Lecture notes, JATE Kiadó, Szeged.

Lassey, K. R., Enting, I. G. and Trudinger, G. M., 1996: The Earth's radiocarbon budget. *Tellus 48B*, 487-501.

Lukács, B., 1994: *Environment management in aspect of a physicist (in Hungarian)*. Természet- és Környezetvédő Tanárok Egyesülete, Budapest.

Perry, H. and Landsberg, H. H., 1981: *Predpolagaemoe mirove potrebljenije energii. Energia i klimat*. Gidrometizdat, pp. 55-97.

Rambler, M. B., Margulis, L. and Fester, R., 1989: *Global Ecology*. Academic Press, Boston-New York-London.

Sabady, P., 1980: *Utilize of solar energy in architecture (in Hungarian)*. Műszaki Könyvkiadó, Budapest.

Schönwiese, C. D., 1995: *Klimaanderungen, Daten, Analysen, Prognosen*. Springer Verlag.

ACTA CLIMATOLOGICA
Universitatis Szegediensis, Tom. 31A, 1998, 17-25.

THE JOINT INFLUENCE OF METEOROLOGICAL EVENTS FOR LIGHT-TRAP COLLECTING OF HARMFUL INSECTS

J. PUSKÁS[1], L. NOWINSZKY[2] and L. MAKRA[3]

[1] *Department of Geography, Berzsenyi Dániel Teachers' Training College, P.O.Box 170, 9701 Szombathely, Hungary*
[2] *Department of Technology, Berzsenyi Dániel Teachers' Training College, P.O.Box 170, 9701 Szombathely, Hungary*
[3] *Department of Climatology and Landscape Ecology, József Attila University, P.O.Box 653, 6701 Szeged, Hungary*

Összefoglalás - Az Országos Meteorológiai Szolgálat 1967 és 1990 közötti "Időjárási események naptára" adataiból az instabilitási vonal, a konvergencia zóna, a ciklogenezis, az országos eső, a hideg- és a meleg frontok, a tengeri- és szárazföldi mérsékelt, sarkvidéki és szubtrópusi légtömegekkel összefüggésben vizsgáltuk meg a vetési bagolylepke (Scotia segetum Schiff.) repülési aktivitást tükröző fénycsapdás fogási eredményeit. A vizsgált időszakban 64 fénycsapda 3232 éjszaka során 29832 példányt gyűjtött. Mivel egy-egy éjszakán több fénycsapda is működött, 25021 megfigyelési adatot dolgozhattunk fel. Megfigyelési adaton 1 állomás 1 éjszakai fogási adatát értjük. Az időjárási eseményekre vonatkozó adatokat annak megfelelően csoportosítottuk, hogy egy-egy napon melyek fordultak elő önmagukban vagy együttesen. Külön csoportba rendeltük azokat a kombinációkat, amelyek időjárási esemény nélküli napot követtek é s azokat is, amelyeket valamilyen időjárási esemény előzött meg. A fogási adatokból állomásonként, nemzedékenként és naponként relatív fogás értékeket számítottunk. Ezeket hozzárendeltük az időjárási események napjaihoz, valamint az azt megelőző és követő 2-2 naphoz is. Ezután naponként összegeztük és átlagoltuk az értékeket. A naponkénti átlagértékek eltérésének szignifikancia szintjét valamennyi csoporton belül t-próbával ellenőriztük. 95%-nál magasabb szignifikáns eltérést összesen 36 csoportban találtunk. Az egyes események gyűjtésre gyakorolt kedvező vagy kedvezőtlen hatása akkor a legerősebb, ha nem egymagukban, hanem más eseménnyel egyidejűleg, esetleg rövid időn belül egymást követően lépnek fel. Eredményeink egyértelműen azt bizonyítják, hogy az egyes időjárási események fénycsapdás gyűjtést befolyásoló hatását nem elég önmagukban vizsgálni. A csapdázás eredményessége ugyanis az egyes időjárási események különböző kombinációitól függően módosul és csak ritkán egyezik meg az önmagában fellépő eseményhez kapcsolódó fogási eredménnyel.

Summary - The light-trap collecting results - showing its flight activity - of turnip moth (Scotia segetum Schiff.) were examined connected with the instability line, the convergence zone, the cyclogenesis, the country-wide rain, the cold- and warm weather fronts, the maritime- and continental moderate, arctic and subtropical air masses used the data published in "Calendar of weather phenomena" between 1967 and 1990 by National Meteorological Service. There were 29 832 moths caught during 3 232 nights by 64 light-trap stations in the examined period. During one night more light-traps operated, therefore 25 021 observing data were worked up. We mean by observing data the catching data at one night at one observing station. The data of meteorological events were collected into groups according to their occurrence on one day alone or together with other ones. They were collected into separated groups according to arriving after a day without any meteorological events or if there were any of them on the previous day. The values of relative catch (RC) were calculated daily for each observing stations and generations used the catching data. There was made a comparison between the relative catch (RC) values and the meteorological events belonging to the date and also on previous and following 2 - 2 days. After it the relative catch values were summarized and averaged daily. The differences of daily average values of significance levels were controlled by a t-test in all the groups. More than 95% significance levels were found in 36 groups. The favourable and unfavourable influence of each events are the strongest at that time, when they have influence not only alone, but also with other effects simultaneously, or they follow one another in a short time. Our results prove clearly, it is not enough to examine alone the modifying influence of each meteorological events for light-trap collecting. The success of light trapping is modified depending on several combinations of each meteorological events and they are not very often the same as the catching result of event to have an influence alone.

Key words: instability line, convergence zone, cyclogenesis, country-wide rain, weather fronts, air masses, insect, light trapping

INTRODUCTION

The insects' phenomenon of life exerting influence of meteorological events are examined generally with the atmospherical process taking to pieces for elements the authors of publications in literature. It is clear that the joint influence of meteorological events has more importance according to the living creature, but publications dealing with these researches are less known. The influences of air masses and weather fronts for light-trap collecting of insects were studied by *Wéber* (1957, 1959) among Hungarian researchers. *Kádár and Szentkirályi* (1991) showed, the number of light-trapped ground beetles (Coleoptera, Carabidae) are the less on the day of arriving convergence zone and on following day of arriving instability line. We could not find fundamental publications on this theme in the foreign literature. The modifying influence of collecting connected with 22 kinds of air masses and 20 kinds of weather fronts and discontinuity levels determined after Berkes (1961) - were examined in our publications (*Puskás et al.*, 1997; *Örményi et al.*, 1997). These papers will be published in the near future. The air masses, the weather fronts and the discontinuity levels were determined for surrounding of Budapest, and unfortunately they are not valid for the whole territory of Hungary (*Csizsinszky*, 1964). We spread our examinations for the joint influence of meteorological events (weather fronts, air masses, instability line, convergence zone, cyclogenesis and country - wide rain). These pieces of information are part of regular meteorological data and they are simultaneously valid for the whole country, or they pass the territory of Hungary at one night.

MATERIAL

The "Calendar of weather phenomena" - published monthly by National Meteorological Service - contains cold and warm weather fronts and 6 kinds of air masses: arctic continental (Ac), arctic maritime (Am), moderate continental (Mc), moderate maritime

(Mm), subtropical continental (Tc) and subtropical maritime (Tm) ones.

We mean on air masses the wide - spread mass of the air, although physical characteristics (mainly the temperature and degree of humidity) change horizontally continuously, but their changes are very small, and their vertical dispersions are almost the same.

The instability lines, the convergence zones, the point of time and length of time belonging to cyclogenesis and the country-wide rain are found in the above-mentioned "Calendar of weather phenomena".

The instability line (squall line) is a convective activity, which moves in a band or line. The short-term intense strengthening of wind speed is the characteristic of its passing and after it violent tempest and thunderstorm come. The convergence develops if two atmospheric motions come from two different directions in the atmosphere. Generally this process takes place along long line, the air accumulates here and one part of it rises up high. It comes often with weather fronts and cyclons. Cyclogenesis is the developing or strengthening of cyclonic circulation.

The catching results of turnip moth (Scotia segetum Schiff.) were analysed connected with these meteorological events. We used the data of light-trap network in Hungary used uniformly the Jermy type light-traps. The light source is a 100 W normal light bulb at 2 meters above the ground, colour temperature: 2900 K, the killing material is chloroform. The traps of the plant protection worked from 1st April to 31st October, while the forestry ones all the year round, independently of the time of sunrise and sunset, every night from 6 p.m. to 4 a.m. All time data are given in universal time (UT). The insects trapped during one night were stored in one bottle, so the whole catch of one night at one observational site is interpreted as one observational datum.

The collecting data of turnip moth (Scotia segetum Schiff.) were used for examinations getting from 64 observing stations of national agricultural and forestry network operated between 1967 and 1990. During 3 232 nights 29 832 individuals were caught by the traps. We used 25 021 observing data in our examination. We mean by observing data the catching data at one night at one observing station independently of caught moth number.

METHODS

The number of individuals trapped at different observation sites and times cannot be compared to each other even in the case of identical species, as each trap works in different environment factors constantly vary according to time as well. To solve the problem, from the catch data we calculated relative catch (RC) values for observation sites, species and generations. RC is the quotient of the number of individuals caught during the sampling interval (1 night), and the mean values of the number of individuals of one generation counted for the sample interval. In this way, in the case of expected mean number of individuals, the value of relative catch is 1.

The data of meteorological events were collected into groups according to their occurrence on one day alone or together with other ones. They were collected into separated groups according to arriving after a day without any meteorological events or if there were any of them on the previous day. We made a comparison between the relative catch - calculated from the collecting results - and the meteorological events, and also the previous and following 2 - 2 days. Then it the relative catch values were summarized and averaged daily. The differences of daily average values of significance levels were controlled by t-test in all the groups.

RESULTS

The light trapping success of turnip moth (Scotia segetum Schiff.) connected with meteorological events is shown in *Table 1*. The significance level was more than 95% in relative catch values in 36 groups.

If the significant difference of value of relative catch is more than 95% level on two following days it is shown with italic numbers. If the value of relative catch differs more than 95% significance level from the relative catch average of summarized all the other data it is shown with bold numbers. The number of observing data are given in parentheses. No meteorological events are in the table, when there are less than 20 observing data, and probably this is the reason they do not show significant differences neither with the previous day's catching nor the average of summarized all the other data.

CONCLUSIONS

The instability line decreases alone the number of caught specimen only at that case, when it repeats during some days. If cold weather front comes after it still the same day, the unfavourable influence can be shown yet the same day. If it comes with other meteorological events the influence is unfavourable or ineffective for catching result. On the following day the quantity of collecting increases only, if subtropical air mass also arrives. The convergence zone is ineffective alone, but if it comes together with cyclogenesis the number of collected moths decreases on the previous day. There is an unfavourable influence if it comes with moderate maritime air mass from the previous day till following day. The collecting results are low on previous day if cyclogenesis can be found alone. On the day of arriving it is also low when it comes with any other meteorological events. If it comes with country - wide rain the catching is low even on the following day. It is remarkable that the country - wide rain alone is favourable before and after the event for success of catching, but if it comes with any other meteorological events the catching is unfavourable for it. The cold weather front arrived alone is favourable on previous days for collecting, but it is unfavourable on the day of arrival and following one. It is also unfavourable if it arrived together with moderate air mass, and collecting is increased by the coming with arctic air mass, but it is decreased on next day. The warm weather front arrived with subtropical air mass is favourable for catching already on previous day and day of arriving, but it is unfavourable if warm front comes with moderate maritime air mass. The number of caught moths is low on day of arriving and following one at coming of moderate maritime air mass and it is independent of combination with any other meteorological events. The catching is not very high - except if it comes with other meteorological event - on previous day of arriving the moderate continental air mass, but it is high on following days. If the instability line on previous day is followed by moderate continental air mass with cold front on day of arriving, the catching of previous night is high, but it is low on following one. If the instability line on previous day is followed by moderate maritime air mass with cold front on day of arriving, the low collecting can be observed on that day will change for high on following one. The subtropical maritime air masses - arrived alone, with instability line and cold front - are unfavourable, but they are favourable on previous and following days. If these kinds of air masses come with convergence zone and cyclogenesis the collecting is small on previous night. The subtropical maritime air masses - arrived with warm weather front - are favourable for success of collecting on previous day and also on day of arriving. The number of caught moths shows decrease on arriving day of subtropical continental air mass and it is the same on next day. The number of collected moths is lower on arriving and following days of subtropical continental air masses. The catching is high on previous and arriving days belonging to the arctic air mass coming with cold weather front, but there is a decrease on following day.

Our results prove clearly, it is not enough to examine alone the modifying influence of each meteorological events for light-trap collecting. The success of light trapping is modified by several combinations of each meteorological events and they are not very often the same as the catching result of event to have an influence alone. At the time of practical utilization of our results everyone has to pay attention to our hypothesis - expressed in one of our former publications (*Nowinszky* ed., 1994) - as the low values of relative catch mean those weather situations in all cases, when the flight activity of insects decreased, but the meaning of high values are not so equivalent. The significant environmental changes cause physiological changes in the organism of insects. The life of imago is short, unfavourable weather endangers not only the continuance of individual but also the continuance of the total species. According to our supposition the individuals can use two kinds of strategies to prevent the hindering influences of normal function in phenomenon of life. The first is the increased activity. It means the growing intensity in flying, copulation and oviposition. The second strategy is to hide and ride out in passivity the unfavourable situation. Seeing the above-mentioned facts, according to our present knowledge high light trapping results can belong to both favourable and unfavourable situations.

The results of these agrometeorological examinations can give chance to make better plant protection prognosis.

Table 1 Relative catches of turnip moth (Scotia segetum Schiff.) connected with meteorological events used the data of light-trap network in Hungary operated between 1967 and 1990. The explanation of abbreviations is in the text

Name of event						Values of relative catches at the days around events					
Number	Previous days	On the day event				-2	-1	0	→0	1	2
1.	Ø	Inst.				1.17 (232)	1.01 (254)	*1.17* (317)	***0.55*** (39)	*0.95* (143)	1.01 (110)
2.	Ø	Conv.				1.04 (236)	0.98 (297)	1.05 (391)	1.06 (457)	1.16 (284)	1.02 (189)
3.	Ø	C				*1.00* (142)	***0.86*** (166)	*0.99* (395)	***0.86*** (222)	0.93 (367)	0.93 (264)
4.	Ø	CF				***1.29*** (81)	***1.36*** (81)	0.89 (279)	***0.56*** (53)	*1.07* (243)	1.09 (180)
5.	Ø	CR				**1.76** (52)	***1.78*** (72)	***1.22*** (76)	1.04 (28)	*1.13* (58)	***1.47*** (56)
6.	Ø	Mc				*1.05* (91)	***0.66*** (90)	***1.34*** (90)		**1.32** (47)	**1.51** (44)
7.	Ø	Mm				0.61 (20)	0.50 (16)	**0.64** (96)		***1.31*** (82)	***0.76*** (71)
8.	Ø	Sc				***0.64*** (79)	*1.03* (87)	*0.95* (108)		***0.50*** (39)	***0.56*** (31)
9.	Ø	Sm				**1.54** (55)	***1.36*** (68)	*0.97* (99)	***0.80*** (59)	***1.24*** (47)	**1.32** (47)
10.	Ø	Inst.				1.11 (148)	1.02 (155)	0.97 (155)		0.96 (43)	0.87 (34)
11.	Ø	Inst.	Mm			*1.05* (74)	***1.22*** (79)	***0.94*** (96)	1.10 (28)	1.17 (17)	1.42 (16)
12.	Ø	Inst.	CF	Sm		1.11 (148)	***1.53*** (25)	***0.86*** (27)		***1.57*** (30)	***1.35*** (27)
13.	Ø	Inst.	CF	Mm		1.02 (209)	1.03 (368)	**0.96** (304)		***0.92*** (306)	***1.14*** (252)

Table 1 continued

Name of event						Values of relative catches at the days around events					
Number	Previous days	On the day event				-2	-1	0	→0	1	2
14.	∅	Inst.	CF	Sm	Am	*1.12* (29)	*0.77* (29)	*0.97* (28)		***1.78*** (29)	*1.24* (27)
15.	∅	Inst.	CF	Mm	Sm	***1.23*** (22)	***1.51*** (51)	*1.03* (50)		***0.74*** (36)	*1.19* (34)
16.	∅	Inst.	CF	Mm	CR	*1.06* (30)	***0.78*** (32)	***0.73*** (35)		***0.59*** (34)	*1.07* (35)
17.	∅	Conv.	C	Sm		***1.43*** (25)	***0.85*** (28)	*1.04* (21)			
18.	∅	Conv.	C	Sm	CR	***1.20*** (22)	***0.81*** (22)	*0.94* (21)			
19.	∅	Conv.	Mm			***1.46*** (35)	***0.82*** (38)	***0.72*** (52)		***0.44*** (29)	***0.93*** (27)
20.	∅	C	CR			*1.05* (94)	***0.93*** (134)	**0.64** (202)	0.98 (75)	*1.01* (180)	***1.35*** (94)
21.	∅	C	Mm			1.07 (62)	*1.04* (69)	***0.79*** (95)	1.03 (14)	*1.03* (103)	1.06 (90)
22.	∅	C	Mm	CR		***1.25*** (49)	***0.66*** (71)	**0.62** (104)		***0.80*** (60)	0.96 (57)
23.	∅	C	Am	CR			1.06 (25)	**0.90** (42)		***0.87*** (38)	***1.49*** (41)
24.	∅	CF	Mc			***0.75*** (218)	*1.05* (245)	*1.09* (318)		*0.97* (266)	***0.76*** (199)
25.	∅	CF	Mm			1.02 (993)	*1.03* (1201)	***0.92*** (1630)	**0.88** (156)	**0.94** (1463)	**0.94** (1392)
26.	∅	CF	Mm	CR		1.02 (34)	*1.07* (56)	**0.75** (72)	**0.71** (21)	**0.83** (73)	**0.66** (58)

Table 1 continued

Name of event						Values of relative catches at the days around events					
Number	Previous days	On the day event				-2	-1	0	→0	1	2
27.	∅	CF	Ac			*0.98* (45)	***1.21*** (59)	***1.16*** (73)		***0.46*** (63)	*0.99* (36)
28.	∅	CF	Am			0.94 (156)	*1.01* (208)	***1.22*** (228)		***0.92*** (203)	0.98 (173)
29.	∅	CF	Am	CR			*0.97* (46)	***0.70*** (48)		***0.90*** (23)	
30.	∅	WF	Sm			**1.38** (50)	**1.54** (60)	**1.66** (73)		1.18 (16)	
31.	∅	WF	Mm			0.96 (33)	***0.81*** (50)	***0.48*** (68)		*0.96* (39)	***1.35*** (30)
32.	∅	WF	Mc			0.91 (22)	***0.42*** (45)	***1.27*** (45)			
33.	Inst.	CF	Mc			1.11 (58)	**1.15** (60)	***1.12*** (62)		***0.95*** (60)	0.97 (33)
34.	Inst.	CF	Mm			0.99 (54)	*1.00* (69)	***0.42*** (68)		*1.00* (51)	**1.30** (46)
35.	Inst.	CF	Mm	CR		*1.11* (44)	***0.83*** (39)	***0.53*** (36)		*1.19* (25)	
36.	Conv.	CF	Mm			0.92 (45)	*1.02* (49)	***1.48*** (54)		*1.08* (33)	1.05 (20)

Acknowledgements

We hereby express our gratitude to Dr. Pál Szontagh, Doctor of Agricultural Science for collecting data coming from light-traps of forestry, Dr. András Vojnits, senior research-fellow at Museum of National Sciences and Györgyné Mohai research-fellow at Budapest Phytopathological and Soil Protecting Station for collecting data coming from light-traps of plant protection stations and agricultural ones.

REFERENCES

Berkes, Z.,1961: Air mass and weather types in Carpathian Basin (in Hungarian). *Időjárás 65*, 289-293.

Csizsinszky, M.,1964: Validity of Budapest front calendar in Hungary (in Hungarian). *OMSZ Beszámolók az 1963-ban végzett tudományos kutatásokról II*, 95-98.

Kádár, F., Szentkirályi, F., 1991: Influences of weather fronts on the flight activity of ground beetles (Coleoptera, Carabidae). *Proceed. of the 4th ECE/XIII. SIEEC, Gödöllő*, 500-503.

Nowinszky, L. [ed.], 1994: *Light trapping of insects influenced by abiotic factors. Part I.* Savaria University Press, 155.

Örményi, I., Nowinszky, L., Puskás J., 1997: Light trapping of heart-and-dart moth (Scotia exclamationis L.) connected with the air masses and the height of tropopause (in Hungarian). *Növényvédelem* (in press).

Puskás, J., Nowinszky, L., Örményi, I.,1997: Light trapping of heart-and-dart moth (Scotia exclamationis L.) at the time of weather fronts (in Hungarian). *Növényvédelem.* (in press).

Wéber, M., 1957: The connection between air masses and quantity of insects flying to light (in Hungarian). *Pécsi Pedagógiai Főiskola Évkönyve*, 295-302.

Wéber, M., 1959: Influence of the front variation on insects flying to light (in Hungarian). *Pécsi Pedagógiai Főiskola Évkönyve*, 259-275.

ACTA CLIMATOLOGICA
Universitatis Szegediensis, Tom. 31A, 1998, 27-35.

MODEL OF SPATIAL DIFFERENTATION OF TEMPERATURE IN KOLOZSVÁR (ROMANIA)

R. GÉCZI[1] and K. LOERINCZ[2]

[1] *Department of Physical Geography, József Attila University, P.O.Box 653, 6701 Szeged, Hungary*
[2] *Department of Physics, University of North Texas, P.O.Box 305370, 76203 Denton, Texas, USA*

Összefoglalás - A cikk Kolozsvár területének hőháztartás-modelljét mutatja be. A szerzők a különböző városi felszínek (beton, aszfalt, víz- és zöldterület) eltérő termikus tulajdonságait alapul véve, a nap négy jellegzetes időpillanatának ábrázolására vállalkoztak. A modell megszerkesztésére a végesdifferencia módszerét használták. Mindez ideális meteorológiai körülményeket, egy hidegfront elvonulása utáni nyári napot feltételez. Ilyen ideális körülmények voltak 1997. június 6-án, amikorra a tanulmány vonatkozik. A modell szerint napközben a város leghidegebb felszíneit a vízfolyás és a zöldterületek képezik. Ezzel szemben a legmagasabb hőmérsékletű térségeket a beton- és az aszfaltfelszínek jelentik. A legnagyobb hőmérsékletű eltérések este és éjszaka mérhetők.

Summary - The structure of urban area may give some different effects on the surface radiation the heat budget and also the heat island phenomenon. The aim of the paper is to study how the urban climate is influenced by different surfaces which characterise the city area. In order to receive a more comprehensive understanding of the thermal patterns in and around urban areas in a themperate climate, the present study was carried out in a different urban areas (e.g. green and water surfaces, streets). Important objectures are:
- to study if the diversified size of the multivarious urban influences the magnitude of the temperature difference between the different style of built-up area;
- to study in what way the density and the structure of the built-up area respectively influences temperature pattern;
- to study the alternation of upwarming and cooling rate in the green and built-up area and its dependence on changes in cloud cover.

The city of Kolozsvár (Cluj, Romania) has been chosen as study area. The study is caried out with the help of physical model using computer simulations.

Key words: heat island, thermical model, thermical conductance, urban area.

INTRODUCTION AND THE INVESTIGATED AREA

The investigation of effects modifying climate in human settlements is a very important topic of urban ecology. During the recent decades the urban areas and the ratio of urban population have grown continuously so the analysis of modifying effects and their physical explanation are required. On the other hand the city should be considered as a whole system, which includes not only buildings and streets but also infrastructure greenery and energy webs. This system functions on basic processes of energy flow. Our investigation is based on the modelling of the thermical characteristics of different built-up surfaces.

The question is how this arificial modification of the natural environment influences the bioclimatological comfort sensation of human individuals. What are the advantageous and the disadvantageous effects of the modified climate on the population living in urban areas and how long do these effects take in the different parts of the built-up areas?

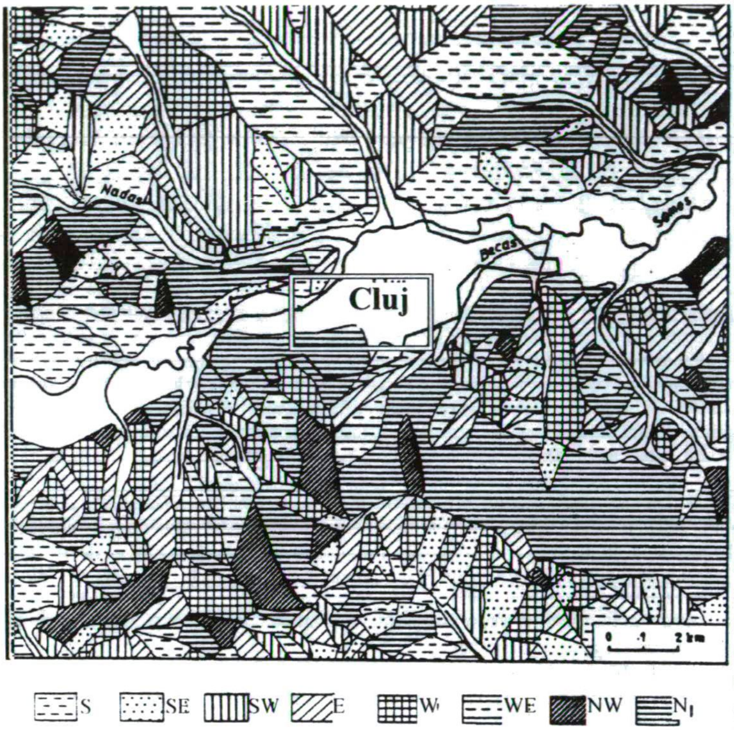

Fig. 1. Exposure of slopes in Cluj and its surroundings

Cluj (Kolozsvár) is situated in the middle north-west part of Romania, at 340 m above the sea level. The territory of the city is extended on ten geomorphological surfaces (e.g. tide land, eight terraces and neighbouring hills). So except the city centre, its geographical situation is not favourable to have relatively undisturbed urban climate (*Fig. 1*).

METHODS

The investigation supposes a common summer day with optimal meteorological conditions. That means calm period which occurs after a cold front and cloudless sky. Such conditions occured on 6th June 1997, when the data of this study were registered.

The work supposes the following steps:

1. Preparing the map.
2. Defining the cities built up environment index. Usually two categories of urban areas are distinguished: open and built-up ones. According to these categories, a land-use classification of each 200 m square was adopted and scored:
   - 2.5 for very densely built up territory
     (concrete, asphalt, bitumen, brick and roof tile surfaces)
   - 2.0 for districts without gardens
   - 1.5 for neighbourhoods with green patches
   - 1.0 for suburbs with gardens
   - 0.0 water surfaces.
3. Solving the differential equation for thermical system:

$$[cT(r,t)]+[T(r,t)] = f(r,t)$$

where t representes time, c is heat capacity, is the density of materials, is the thermical conductance, f is the source density (sunshine, irradiation, etc.) and r is the relative coordinate (x,y). The result is T temperature given in °C.
4. Plotting the results.

Modelling the thermal characteristics of an urban area is a very difficult problem. There are many parameters and large scales. Handling this large amount of data requires special techniques in numerical methods and in programming. Solving the differential equations which control heat flow in environment needs very large memory to store data and long calculating time to reach proper accuracy and resolution enough in space. In this case like description of urban area in two dimension with initial and boundary conditions some different methods exist from which we selected the so called finite difference method. This technique is the most applicable in our case, because we can disregard some not so important things. We shall approach the real problem with very similar but much simplest model which is able to produce effect in which we are interested. Supposing that the examined territory is flat with some different pattern styles like green patches, buildings from concrete slabs, gardens, parks and water surfaces. We have to make some steps to reach to the calculations. First of all preparation of map from investigated urban area it is necessary to make an scanned picture from paper map and to clear the not necessary details like names of streets an other marks from bitmap picture. After that some different but well defined colours is converted in the different areas, which corresponds different heat capacity and irradiation coefficients.

The next step is to solve the differential equations for this system by taking in account that every pixel corresponds with a different heat emitter which is defined by altitude of sun. The differential equation that we have is the common equation for the heat diffusion processes. In this modelling for initial values we set the totally equal values for over the city. The boundary conditions at the edge were fixed temperatures which are defined by average over city temperature in each time step. This pixel is building up the plane using Descartes coordinate system with variables x and y or in vector for written using r symbol. Supposing that is the clear, not cloudy day without any wind motion. This one is mostly after weather change in summer. In this way we can write set of equations and can solve it with iteration methods to receive testable result. In the next step changing the radiation which influences heat source and doing again the calculations with new conditions you get the time evolution of temperature map of investigated area. Reaching the typical daytime we saving the information to bitmap picture in which every pixel describes the temperature in every position. We are interested only in the special daytime temperature. However, we must carry out the calculations through time step by step. If we are interested in the time evolution of selected point we must use a different plotting view. For example, if we knew how the temperature evolves at given coordinate in time, we should get a two dimension plot showing temperature versus time. Thus we have the final result but to make a better quality we have to rescale the temperature map in this way we can show better the temperature differences between different areas and at different time as well.

RESULTS AND DISCUSSION

At 2 p.m. the spatial distribution shows the highest temperature, heat islands in the town centre and the territory which are built-up from concrete (factories, sports grounds) situated in the north-west. The housing estates appear the second warmest area of town (*Fig. 2*). This area - in the south and south-west part of the map - is a housing estate with 4-10 storey buildings, which are built from concrete slabs and rubble, and its building-density is relatively high. Along the river the large mass of water moderates temperature extremities thus in the afternoon it decreases temperature. Cold areas appear at mainly vegetated open spaces like parks, cemetery, citadel (the former citadel does not exist, its place is occupied by family houses with large gardens and open parks area) and the esplanade. Between the two extremitiesmoderately warm up territories are situated like the suburbs, the neighbourhoods with green patches, open spaces with grass and the built-up areas with detached houses, especially those with vegetation (mainly situated in middle and in the south-east part of the city). The difference between the very upwarmed and relatively warm areas are more of 9°C (*Fig. 3*).

The map at midnight shows a relatively balanced situation (*Fig. 4*). The warmest areas are the riverbank and around the esplanade where the temperature is higher than 20°C. On the other hand the concrete and bricks surfaces where the vegetation is completely absent are turned cold. The highest difference of the temperature in the city is around 7°C. The temperature decreases step by step until 5 a.m., when almost all thermical differences are coming to an end: they reached just 4°C (*Fig. 5*).

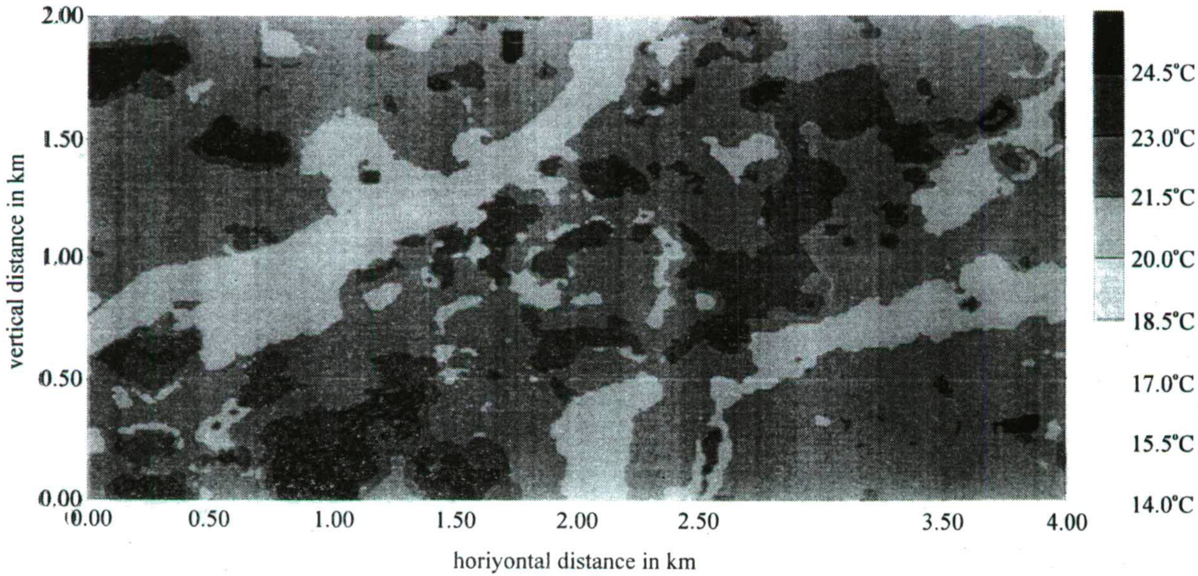

Fig. 2 Temperature map at 2 pm in °C

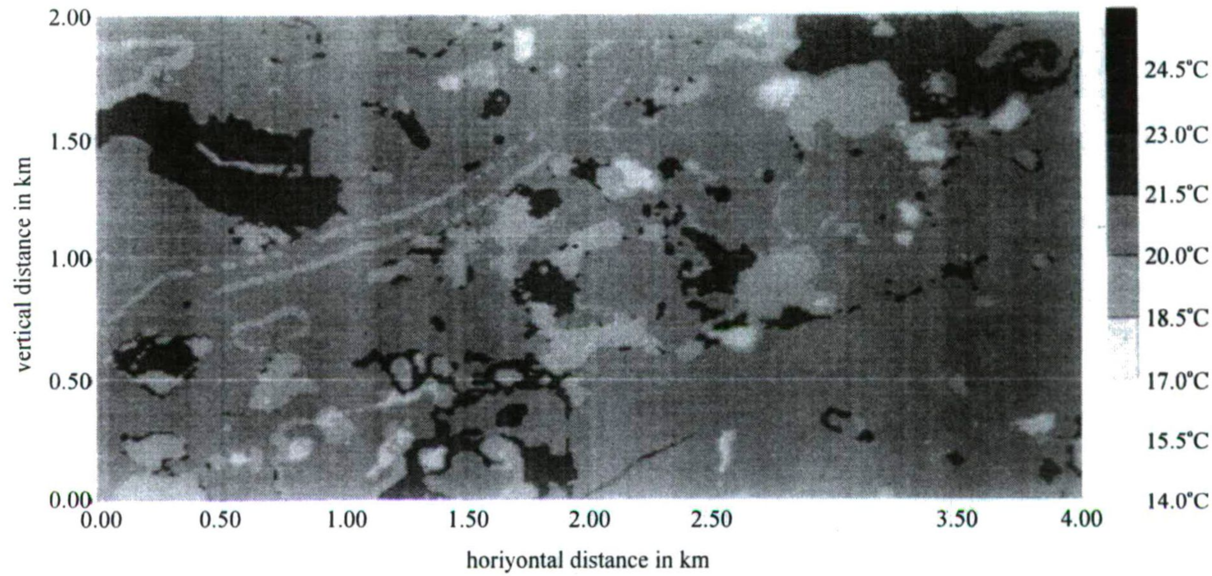

Fig. 3 Temperature map at 7 pm in °C

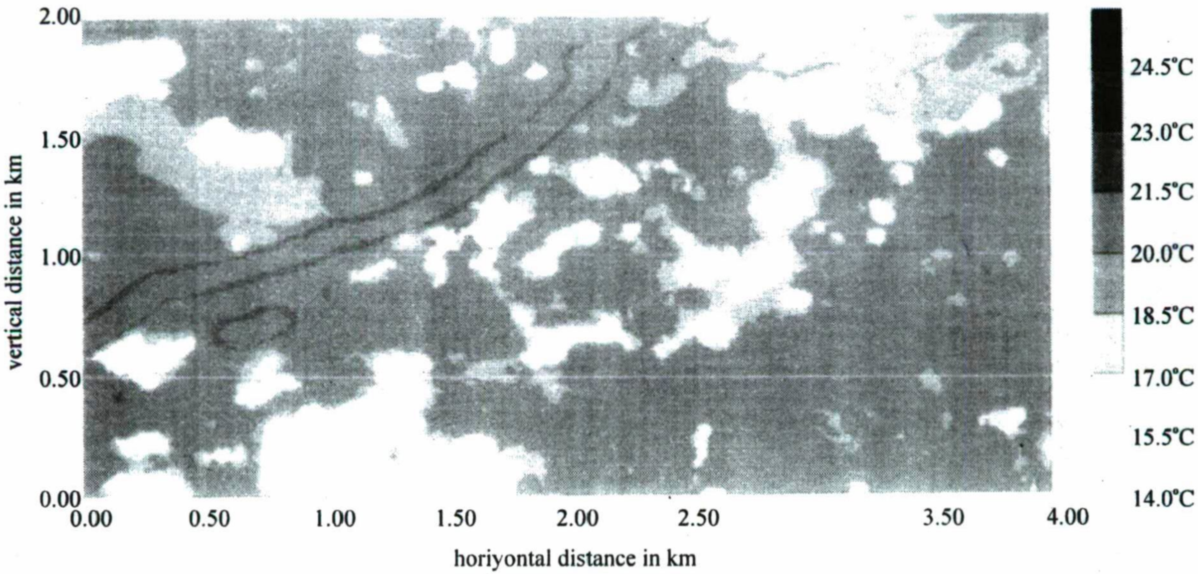

Fig. 4 Temperature map at midnight in °C

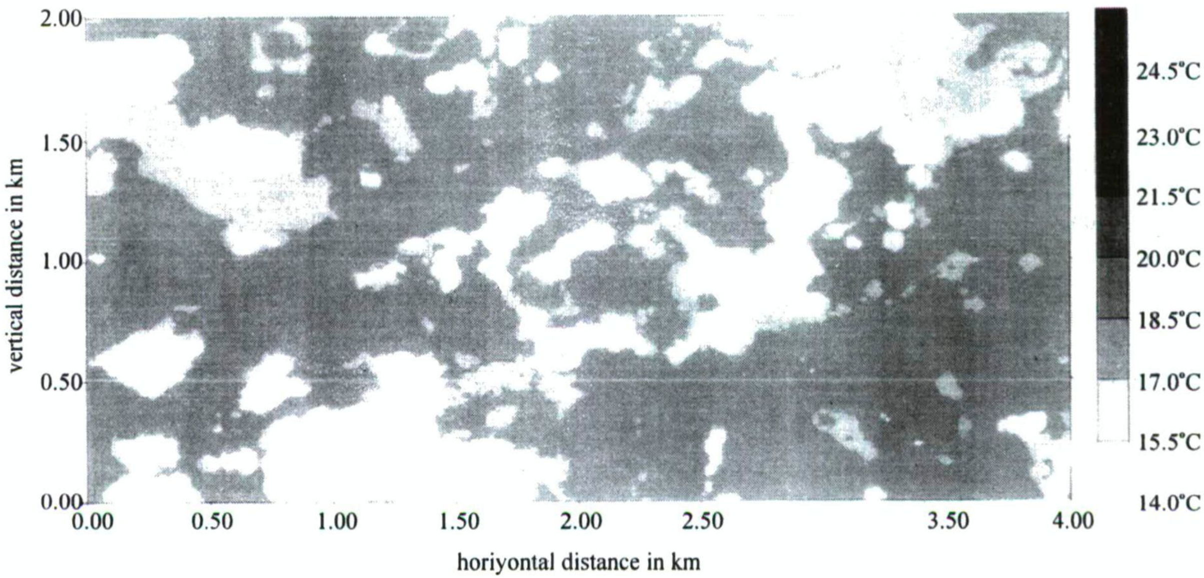

Fig. 5 Temperature map at 5 am in °C

REFERENCES

Belozerov, V., 1972: Climate of city Cluj and its surroundings (in Rumanian). *Doctoral Thesis*, Cluj.
Goode, D., 1997: The integration of urban nature in urban development. *Proceedings of International Conference on Urban Ecology, Leipzig.*
Imre, L., 1983: *Heat transfer in complex structures (in Hungarian).* Akadémiai Kiadó, Budapest.

ACTA CLIMATOLOGICA
Universitatis Szegediensis, Tom. 31A, 1998, 37-50.

SOME NOTES TO THE PERMOTRIASSIC CLIMATE IMPLICATIONS FROM MAMMALOGENESIS

B. LUKÁCS[1] and Sz. BÉRCZI[2]

[1] *Central Reseearch Institute for Physics RMKI, P.O.Box 49, 1525 Budapest 114, Hungary*

[2] *Departments of G. Technology & Petrology and Geochemistry, L. Eötvös University, Rákóczi út 5., 1088 Budapest, Hungary*

Összefoglalás - A terapsida hüllők késő ókori és középkori evolúciója bizonyos adatokat szolgáltat e korszak őséghajlati feltételeire. Összevetjük a terapsidák által elért fejlődést az őshőmérsékleti becslésekkel, és bizonyos javításokat sugallunk a permi eljegesedés befolyására.

Summary - Late Paleosoic and Mesosoic evolution of therapsid reptiles gives some constraints on paleoclimatic conditions during these periods. We compare the basic achievements of therapsides during this period with the paleoclimatic estimations and suggest some improvements on the profile of the Permian glaciation.

Key words: paleoclimatology, P/T boundary, therapsids, anoxia.

1. INTRODUCTION

Permian (and Triassic) times converted some synapsid reptiles into mammals, a very important grade development. In addition the Permian showed repeated glaciations, absent in the next 200 Ma. There was a big but obscure catastrophic event too on the P/T boundary. So Permotriassic was an interesting period for climate/environment. Some reconstructions do exist, but the era is more than thrice older than the popular C/T boundary about which there is still controversy. Therefore the reconstructions are not so reliable.

But the development of synapsids towards a mammal stage must imply something for climate/environment, as seen from the fact that later reptilian diapsids returned and dominated mammals and mammal-like reptiles for some 120 Ma ("the dark age of mammals"). So mammals were not "optimal" then; they were better adapted to *some* climate/environment. If so, then comparisons between environmental reconstruction and therogenesis may help fill holes of both. The present paper is such an attempt.

The problem may seem simple. If cold climate (present in some Permian times) is sufficiently long, then outside the tropical regions all reptiles are converted finally into endothermic animals with high metabolic rate, developed feeding apparatus etc. This suggests as if hair, dominant dentale, secondary jaw articulation, vivipary and lactation had all been responses to the challenge of cold, in which case the success of mammals would have been predetermined. But the paleontologic finds do *not* support such a simple picture: the cold climate ended when the therogenesis was only halfway. Maybe this explains the subsequent long "mammalian dark age" too. We think that at least 2 environmental data must be compared to facts of therogenesis: temperature *and* atmospheric oxygen content. (The CO_2 level seems redundant: it was never high enough to affect animals directly, onto them it acted via temperature as a greenhouse gas.)

In addition, the evolution must have been once interrupted (disturbed?) by a catastrophe of obscure origin at the Perm-Triassic boundary. In the seas this catastrophe killed life almost globally; on lands it was less lethal but still serious. The Permotriassic evolution seems rather involved.

In Chapt. 2 we recapitulate a detailed reconstruction for paleotemperatures. In Sects. 3-6 we follow therogenesis in the Permian, at P/T boundary, in Triassic and in Jurassic times, respectively; at the end of Jurassic mammals are practically ready albeit still obscured by dinosaurs, and according to many authors split into the present eutherians, metatherians and atherians happened in the uppermost Jurassic or in basal Cretaceous. Sect. 7 tells about a possible (albeit unproven) solar mechanism for an oscillation of Sun between a "normal" and a "cool" mode of operation (then we would now be in the "cool" one), and Sect. 8 recapitulates the reconstruction for the oxygen content. The emerging picture is uncertain but coherent. Chapt. 9 gives some brief conclusions.

2. RECONSTRUCTIONS FOR THE PERMIAN GLACIATIONS

Since the time of the First World War it has been known that on the southern hemisphere substantial territories were permanently covered by ice roughly in the Permian. While the involved areas seem almost random on a recent map, global tectonics gives a very clear picture: the subpolar territories of the southern supercontinent Gondwana was then glacial.

Maybe in 1912 Wegener was the first who took seriously the traces of Permian glaciation. As an explanation he tried with the shift of continents and regrouped all parts of Gondwana to the neighbourhood of the South Pole. The mechanical model behind the continental shifts was quite wrong, therefore the idea was rejected. However in the 30's Du Toit, a Boer with thorough knowledge about South African layers, collected many data about Permian glaciers, determined the directions of ice "flows", and the facts clearly indicated touching continental shores. What is more, it seemed that the pole was somewhere in South Africa.

However recently we have learnt that a polar or subpolar location in itself is not enough for permanent ice cover. E.g. it turned out that the Antarctic permanent ice is not older than 5.5 Ma. Instead of complicated arguments let us use a simple one. The Milankovic theory of repeated glaciations is based on quasiperiodic changes of eccentricity and axial tilt of Earth by gravitational perturbations. The scale time can be calculated as several myriad years. Some combinations of orbital parameters result in small seasonal changes, e.g. with small eccentricity and minimal possible tilt the seasons are not too expressed. Then on the moderately cold winters snowfall is substantial, the subsequent tepid summer cannot melt *all* the snow and therefore around (at least one of) the pole(s) the white ice cover starts to expand. This cover has a high albedo and therefore the global terrestrial temperature starts to decrease. So obviously quasiperiodic glacial eras indicate permanent ice at least at the pole.

Recently (at least in the last 2-3 Ma) glaciations are repeated. But not it was so before mid-Pliocene. Therefore before mid-Pliocene the annual mean temperature of Earth must have been so high that even at the poles practically all the ice and snow melted in summers. Now there is a circumpolar continent on the southern hemisphere, which is optimal for permanent ice. Hence one guesses a mean terrestrial temperature definitely not higher than the present one, for Permian during the glaciations. Now, *Budyko et al.* (1987) reconstructed paleotemperatures, with the result that during practically all the Permian temperature had a local minimum compared to end-Carboniferous and Lower Triassic but with some global mean temperature 21°C. *Budyko et al*'s temperature curve is redrawn on *Fig. 1*; absolute times, for comparison, are everywhere in this paper rescaled to the averages of the 2 timescales in *Farquhar* (1967).

This temperature is cca. the same as for the Paleogene/Neogene border in the same reconstruction. Now at that time there were definitely no glaciations. As told above, during quasiperiodic glaciations the average temperature drops several °C; and, as an experimental fact we know that the mechanism cannot start at that temperature. Therefore, if we use Pleistocene as an analogy (*Woldstedt*, 1969), we guess a further cooling somewhere in

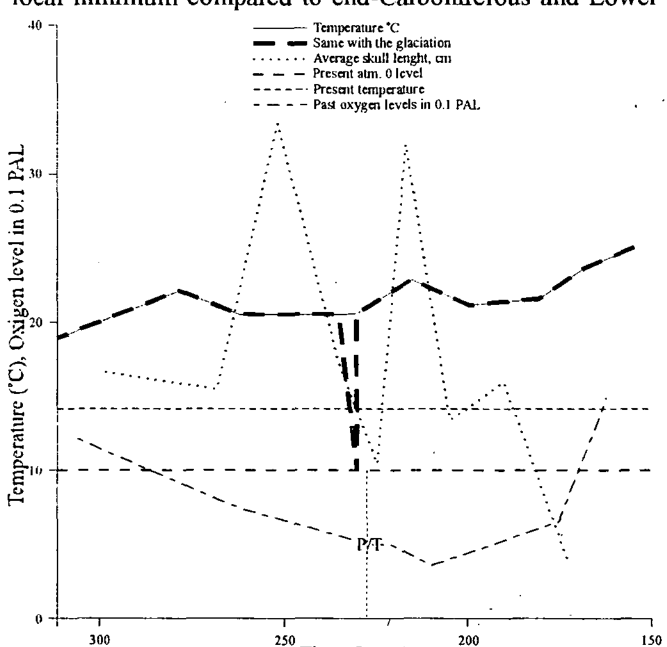

Fig. 1 Reconstructed paleotemperatures, oxygen levels and average synapsid skull sizes. Climatic data are from *Budyko et al.*, skull sizes from *Kemp*, and timescales from *Farquhar*.

the Permian to cca. 16°C, and then an oscillation down to at least 11°C, again shown as a guess on *Fig. 1*. Of course the numbers are based on a similarity between meteorologic processes in eras 300 Ma apart from each other.

3. PERMIAN THEROGENESIS

According to fossil evidences the Permian was very important in the genesis of mammals (therians and relatives). During the Permian synapsid reptiles arrived at advanced therapsid (i.e. mammal-like) stage from a rather primitive stage (*Kemp*, 1982), at the end with diaphragm, endothermy, differentiated teeth, 7 cervic vertebre and the final digital formula (*Kemp*, 1982; *Bérczi et al.*, 1997). As a matter of fact, vivipary, lactation and maternal care cannot be documented from Permian, but it seems that all the advanced synapsids were already on the march toward true mammals at the end of Permian. This fact implies that the evolution of pelycosaurs and therapsids may give further data for the atmospheric conditions in Permian (and Triassic).

But the fact also gives a temptation to explain the evolution of *all* mammalian characteristics with the Permian glaciation. Such an argumentation goes as follows.

Let us assume a prolonged cold and snowy environment in Southern Gondwana when the most advanced vertebrates are reptiles. Then such an environment forces several correlated processes as: thermoregulation (endothermy, hair), higher temperature needing better eating apparatus (differentiated and fitting teeth, stronger mastication therefore a single, rigid bone in the lower jaw, so atrophy of postdentales, dentale/squamosum articulation) and retention of the premature young and feeding later (viviparity, lactation, etc.). I.e. *all* mammalian characteristics might be simply answers to the challenge of cold.

However the facts do not support this monistic explanation. Some important mammalian features seem to have appeared after the glacial times, at or just after the P/T boundary (femur in the parasagittal plane, hair, double circulation), and the true mammals appeared only in the Upper Triassic (*Kemp*, 1982), when the temperature was so high that glaciation was absent. So some other challenge must have been present in the Triassic.

4. THE P/T BOUNDARY

Some disrupting events definitely took place at the Permian/Triassic boundary. First, there was a Great Extinction, quite catastropic in the seas; for aquatic life the greatest up to now. Second, in many places, e.g. at Sasayama, Japan, a definite "dead" layer is seen between end-Permian and basal Triassic (*Ishida et al.*, 1992). Third, the sea level oscillates just at the boundary. Fourth, it seems that at the boundary the spherule content of layers has a peak; although statistical data are accumulating just now, it is sure that a specific "Miono-type" FeO kind of spherules peaked just at the P/T (*Tóth et al.*, 1997). Many analyses showed anoxic and superanoxic conditions at least in seas (e.g. *Erwin*, 1993; *Isozaki*, 1994; *Géczy*, 1996) which may explain the "dead" separating layer.

We do not yet know, what put an end to the good old Paleozoic times. As a working hypothesis, one may think about, e.g., a cosmic impact, disturbing the atmospheric conditions, maybe triggering the activity of volcanoes of whole Siberia (*Kemp*, 1982), causing strange chemistry in the air; the spherules may have come with the impactor, from its surface as droplets, and from the terrestrial matter thrown up by the impact. This is the simplest scenario, because it goes parallelly with the most popular C/T one (when the Deccan volcanoes started) only on a larger scale. The details are still obscure, but spherule counting and analyses may help. E.g. if anoxia was caused by the impact as trigger, then the spherules must be slightly earlier than the anoxia. In addition, if the impact was made by asteroid-sized bodies, then the overwhelming majority of the spherules must be of terrestrial composition according to the phenomenology of impacts. The necessary analyses are going on.

Anything had been the reason, we know from the extinctions that the P/T boundary was hard for life. Synapsid fossil data do *not* show very marked extinction (they show some other signal to which we will return in due course), but some branches died out about the boundary.

Paleotemperature reconstruction (*Budyko et al.*, 1987) does not show anything dramatic at the boundary; it is a starting-point of a temperature increase, to cca. 23°C during Lower Permian. This may have been caused by the volcano activity (emission of greenhouse gases as CO_2 and H_2O), but not necessarily so; the Permian cold may have been simply the previous Fowler cycle (see in Chap. 7), which possibility will be treated later. Of course, if there was an impact, the dust certainly must have caused an "impact winter". However the estimated length of such a cold period is only several years, and already endothermic synapsids, trained by the Permian cold, were probably not too much disturbed by it. The preceeding cold is the only qualitative difference between this P/T scenario and the popular C/T one.

At or just after the P/T boundary advanced synapsids reached the stage of good insulation (hair) and complete double circulation, plus femur in the parasagittal plane. The first advance may have been the proper answer to cold. The second one made possible high peak power of activity. The third one is the present status of locomotion of recent Australian monotremes. It increased the speed of walking and "running" and the double circulation system, with highly oxygenised arterial blood, could yield the necessary higher power.

5. TRIASSIC TEMPERATURES

For Triassic times the temperature reconstruction shows first a relatively fast temperature increase, some 3 centigrades above the Permian level in the Lower Triassic, then a cooling, and a final short heating up (*Koppány*, 1996). The end-Triassic temperature was not much above the Permian level, but it must have been enough to break the Milankovic cycle, because no trace of cyclic glaciation is seen.

The real temperature increase was, of course, higher. Pleistocene reconstructions give cca. 5 centigrades amplitude oscillation between glacials and interglacials. On this basis, as told in Sect. 2, we must guess the global terrestrial time averages at end-Permian not higher than 11 °C; and the end-Triassic one can be guessed from the reconstructions as cca. 22°C.

Therefore *for temperature* the driving force towards mammalian stage was absent during Triassic. Still the evolution did not slow down substantially. During the Lower Triassic the leading therapsids reached a therian stage in the differentiation of hind teeth to premolars vs. molars, produced a proper occlusion of molars, and a secondary lower jaw hinge. During Upper Triassic, in addition, they reached qualitatively the therian dentition and molar cusp pattern, diphyodonty and the characteristic mammal prismatic enamel, triangular motion during mastication, the fundamental structure of skull, completely therian locomotion, brain structure, milk secretion plus hypertonic urine. In some points recent monotremes did not follow the uppermost Triassic innovations.

Some of the Triassic advances simply continue earlier ones; but if we do not want to refer to orthogenesis, driving forces must have still been present. In 2 points the driving force is clear. Diphyodonty is necessary to keep the precise occlusion, and the hypertonic urine may have been forced by aridity. However the majority of other advances (better feeding system plus milk for the young) seem to have been answers to the challenge of generally "hard conditions" in a situation when low temperatures did not pose any challenge any more.

We must analyse the locomotion in slightly more details. For a long time it was believed that vertical femur *and* humerus are energy conserving. But recently it turned out that it is so only if the feet are the only contact points with the ground. Spiky anteaters traverse the same distance with less energy consumption than recent therian mammals of the same mass do it (*Edmeades and Baudinette*, 1975). Now, the recent spiky anteater is at Lower Triassic level for locomotion. The vertical femur gives the momentum at the starting- point of step, then the forelegs with horizontal humerus roll forward the body; then transiently the foreregion of the rump is resting on the ground and the new cycle starts again from behind.

This is indeed an energy conserving way of locomotion, but not so fast as with a vertical humerus. If both meat-eater and prey are therapsids, there is a natural selection force for "erect" quadrupedal gait, provided the environmental conditions are not forcing too much energy conservation. Observe that present Australian monotremes, in the Lower Triassic state of locomotion, are insect-eaters.

6. JURASSIC SITUATION

For completeness' sake we finish this sequence of Chapters with Jurassic. For temperature, Jurassic was hot and uneventful. In the mid-Jurassic the global temperature average was cca. 24 °C, some 10 centigrades higher than the present one.

At the end of Jurassic the therian mammals, albeit primitive and minute, are ready.

But the Jurassic innovations seem rather logical consequences of earlier changes. E.g. the atrophied primary "reptile" Ar/Q joint vanishes, so giving a possibility that both of them go to the ear as malleus and incus, generating much more acute hearing. Also the atlas and axis fuse, giving more possibility for head movements. In these points the Australian monotremes, probably evolving already independently, follow the therians.

So there is no trace of "hard conditions". Indeeed, Jurassic is the beginning of the golden days of large diapsid reptiles. Very probably mammals remained small only for filling niches completely different from those of dinosaurs.

Tritylodonts died out in mid-Jurassic with Stereognathus (*Kemp*, 1982). But this is not necessarily a signal for "hard conditions". Tritylodonts, the last non-mammal therapsids, were specialised herbivores, and still not too different from contemporary mammals. Maybe they concurred with herbivorous mammals and were not so successful.

Diapsid birds separate from dinosaurs sometime in the Jurassic, and they are now homoiotherm with double circulation. But they need high body temperature for flying.

7. FOWLER CYCLES

It is possible that the relatively low temperature of Permian may have had an extraterrestrial, namely solar, explanation. The mechanism was first suggested by *Fowler* (1972) for explaining the present solar neutrino deficiency. For details see the original article, but the scheme is simple enough.

The present solar energy output is very well known. Assume that all of it comes from H > He fusion. Then, with some uncertainty from chemical composition etc., one can count the fusion rate, and for an Ó nucleus formation 2 neutrinos leave Sun. One can detect at least the high energy tail of the neutrino flux by a reaction

$$Cl^{37} + \text{neutrino} \rightarrow Ar^{37}$$

Ar^{37} being radioactive. But when Davis tried to detect the neutrinos, he was first unsuccessful, and finally found some 1/30 part of the first prediction (*Davis et al.*, 1971 vs. *Abraham and Iben*, 1971).

Now, Fowler explained the surprisingly low neutrino flux with a mechanism causing global cooling by several centigrades on a cca. 30 Ma scale. He called attention to the fact that the (Cl, Ar) reaction rate steeply increases with energy, and the highest energy neutrinos come from side reactions as proton capture by B and Be. There the Coulomb barrier is substantial, so their neutrino rates increase with high powers of the central temperature. So an 5-10% decrease of the central temperature may completely explain the very low detection rate. (Later measurements started with Ga as detector material: it is much less energy-dependent and still some 1/3 of the rate is missing.)

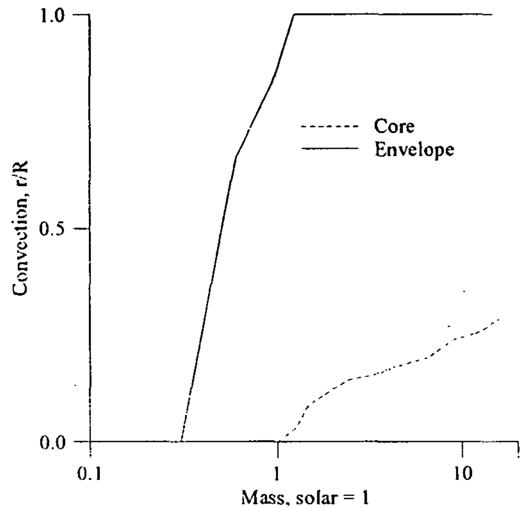

Fig. 2 The borders of envelope and core convections, respectively, vs. stellar mass, after *Schwarzschild and Novotny*. The actual values moderately depend on stellar age too.

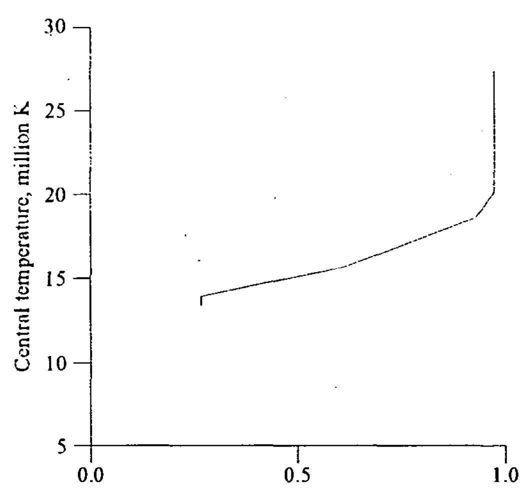

Fig. 3 Solar central temperature vs. central He fraction from a sequence of non-cyclic evolutionary calculations collected by *Novotny*

So there would be no problem *with neutrinos* if the central solar temperature were slightly lower than given by the best simulations. Fowler observed that the Sun of best available calculations (based on slow evolution and primordial chemical composition outside) is not too far from convectional instability at the outer boundary of the core, while convection is present at the surface. Less massive stars are stable for convection inside and convective at the surface, much more massive ones are convective at the core and not at the surface, and in a narrow mass range, in present, non-cyclic simulations starting at 1.1 solar mass, the two convection zones can coexist. (For the borders of the convective zones some stellar interior calculations are shown on *Fig. 2*).

Now take a star with proper mass. First the core is not convective. By the advancing fusion H is converted to He, and during that the particle number of the core is decreasing. Let us start with a given number of NH and NHe, and neglect the heavier elements, practically unchanged. Then the total particle number, being atoms fully ionised, can be obtained by taking the electrons into account as

$$N(t_o).\ 2N_H + 3N_{He} \qquad (7.1)$$

After some time dt the formula is the same but with changed numbers

$$N_H(t_o+dt)=N_H-4rdt;\ N_{He}(t_o+dt)=N_{He}+rdt \qquad (7.2)$$

r being the creation rate of He; resulting e^+'s annihilate with some e^-'s. So

$$N(t_0+dt) = N(t_0) - 5rdt \tag{7.3}$$

But the pressure in the core must not change too much, because it supports the unchanged layers above the core. Then the average core temperature must increase inversely with N, i.e. at least for short periods

$$T_c(t_0+dt),\ T_c(t_0)\{1 + (5r/N(t_0))dt) \tag{7.4}$$

Indeed, evolutionary calculations show that T_c will increase with the central He weight concentration. But with increasing core temperature the rate r goes up first as T_c^4, then the CNO fusion starts too with T_c^{20}, and with the increase of the He concentration in the core this process has a positive feedback. This makes the temperature gradient at the border of the core (outside of which the fusion is negligible) more and more negative. When the absolute value of the gradient is too large, "bubbles" of hot gas can ascend by the Archimede Law, being thinner at the same pressure. The condition *against* convective instability for fully ionised gas is

$$-2d\ln P/dr > -5d\ln T/dr \tag{7.5}$$

(*Schwarzschild*, 1958); note that by the - signs both sides are positive.

Now the left hand side is governed by gravitational equilibrium and so remains more or less the same while the right hand one is by the evolution of core material, as seen above. So the right hand side is continuously growing, and at a moment the core boundary may become convective (if there is enough time).

If so, then convection mixes matter inside and outside the core; the core helium will be washed out, and N will go up again. Then T_c drops, the fusion rate drops too, not to the original value, because the total He content of the star is already higher, but near to. With the fusion rate the total energy output drops too, and on astronomic time scales the star's fusion energy output is a saw-toothed curve superimposed on a slow increase. The gravity equilibrium cannot be instantaneous, so there is a slow expansion during the nonconvective evolution, while there is a contraction just after convection, making the decrease of energy output more gradual.

We emphasize that the calculations for solar interior can reproduce quite good bulk Suns from cca. 1968, but this fact and the stability against core convection at 1 solar mass does *not* rule out a quasicyclic Sun. Namely one initial condition has been chosen by assuming a priori the lack of core convection, and there is no valid theorem against core convection at 1 solar mass.

Namely, for performing an evolutionary calculation we need initial conditions, e.g. for chemical composition. Starting from a galactic gas cloud, it was of course homogeneous in space, and we may assume that the concentrations beyond He were the same as the present values; but some part of the present He was produced in the Sun. However if we *assume* the lack of the core convection *in the whole past*, then the initial He concentration was the same as now on the surface. The non-cyclic solar model is self-consistent, except for neutrino flux.

However if one accepts Fowler's suggestion then the present surface He content is higher than it was in the presolar nebula. In addition, the present solar luminosity contains a non-fusion component too, practically neglected in the non-cyclic calculations. So a whole series of calculations should be started from various initial conditions to see if any of them runs into core convection and after 4.5 Ga into the present Sun with the present luminosity from fusion + contraction. We do not know sufficient methodical and detailed such analyses.

So much about the Fowler cycles qualitatively. But what is the amplitude and timescale of the changes?

Since detailed calculations remained only partly successful, no reliable result exists for the amplitude. However with great uncertainty the 2 timescales can be guessed, and then from the longer timescale the amplitude of the oscillation of central He concentration too. As for the ascending part of the saw-tooth, for a star of one solar mass all simulations give some 10 billion years to consume the majority of core H. Then 1% H depletion needs 200 Ma, and means 1.3% temperature increase. At the present status of art we do not know how near the Sun is to convective core instability (at 1.1 solar mass the timescale must be short); one may tell then that perhaps some 200-1000 Ma would be the ascending slope for 1 solar mass.

For the descending slope the estimations are more qualitative. *Schwarzschild* (1958) guesses that the velocity of convective cells in the interior of a Sun-like star is about 0.03 km/s. Such a cell can traverse substantial part of the star in a year (!), so the mixing times are short on geological or astronomical timescales. However this is *not* the timescale of *luminosity* drop.

Namely, if the whole scenario holds for the Sun, we are now in the low fusion rate so low luminosity phase; however the luminosity fits to the old, non-cyclic models. But not all the luminosity comes from fusion. When the fusion power drops, the Sun starts to cool, the average pressure of the whole body drops too, and gravitational contraction starts. (See, as an example, such stages of *long* timescale in stars in Iben's calculations, cited by *Novotny* (1973).) But this latest process is energy deliberating, so the luminosity does not decrease so much as the reaction rate does. The Sun is an energy buffer, and the characteristic time of this effect is the so called Kelvin-Helmholtz time, the Sun's gravitational energy divided by the normal luminosity. With some minor uncertainties for the internal structure this time is guessed as 30 Ma (*Schwarzschild*, 1958).

From the temperature reconstructions we may guess that the necessary temperature decrease from normal to periodic glaciations is 6-8 centigrades, so 2%. That means a 8% decrease in solar luminosity, or less if the changes of atmospheric CO_2 and H_2O concentrations, with positive feedback to temperature, help. Such changes are not dramatic at all. That needs cca. 2% drop of T_c, i.e. cca. 1.5% of H depletion, which would need slightly more time than 200 Ma. The argumentation is slightly circular, but not impossible.

So, *if* this model works for the Sun, then we can predict several hundred Ma's of normal high temperatures for Earth, separated by, say, 30 Ma's of temperatures continuously decreasing, at the end lower by several centigrades and then quasiperiodic glaciations. What is

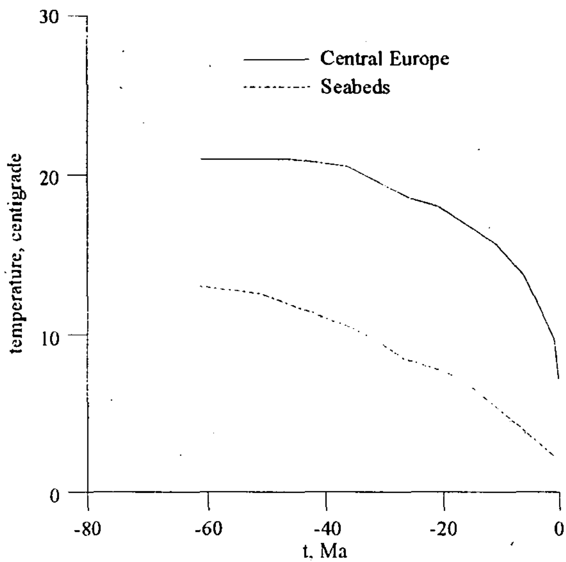

Fig. 4 Tertiary temperatures after *Emiliani and Woldstedt*

really interesting is the well known neogenic cooling (*Fig. 4*) which is appearing on all temperature reconstructions, started just 30 Ma ago (*Emiliani*, 1958), as noted by Fowler himself too. The cycles must shorten as the Sun is filled up by He.

Therefore there is a possibility that the cool Permian was the end of the previous Fowler cycle some 250 Ma ago; and if so the second previous one can be guessed to the end of Precambrian.

The picture is full of holes, but the skeleton is coherent. Detailed astrophysical calculations will decide in the future if this mechanism can work for the Sun, but it is viable for stars with 1.05-1.1 solar mass. This picture was the reason that i) we did not rule out a cooling in Permian from "Paleogenic" temperatures to "Neogenic" ones and that ii) we guessed that the Permian glaciation would have ended even without the P/T catastrophe. But then we can conclude that therapsids did not get enough time to replace the other reptiles without mammalian trends.

8. "HARD CONDITIONS": THE OXYGEN CONCENTRATION

However the therogenesis did *not* stop with the Lower Triassic heating; and the therapsid evolution went by as if therapsids needed the efficient feeding mechanisms, endothermy etc. even in the returning benign climate. And there is indeed one more environmental characteristics which may have meant "hard conditions" for them, and not for the conservative diapsid reptiles.

As we remember, Permian ended with anoxy. It may or may not be connected with the P/T catastrophe, but it certainly existed. *Budyko et al.* (1987) reconstruct the oxygen concentration too. Until Devonian it is always below 1 PAL, there is a local maximum at cca. 1.7 PAL in Lower Carboniferous, it is cca. 0.9 PAL at C/P, and it remains near to 0.8 PAL for the major part of Permian. Then it decreases again, with 0.5 PAL at P/T, still dropping. The minimum is cca. 0.4 PAL in mid-Triassic. There is a rapid increase from T/J, and the concentration is almost 3 PAL in Lower Cretaceous. This is the absolute maximum, going back to 1 PAL in Paleogene. The oxygen concentration from Carboniferous to Jurassic is included too into *Fig. 1*. Now let us see if this curve is coherent with the Triassic and Jurassic therogenesis.

It seems so. At end-Permian the synapsid strategy, spread in many parallel branches of therapsids, was an active adaptation to *cold*. The animals maintained "constant" temperature higher than outside; this was energy-consuming but the feeding apparatus was becoming more and more efficient too. The differentation and occlusion of teeth made new prey, herbs or seeds available and real cutting dentition made them more digestible. Diaphragm made the oxygen intake more efficient and so metabolic rate higher. At Southern Gondwana this was the leading strategy: there were no real opponent land animals during the cold (*Kemp*, 1982). Anapsid or diapsid reptiles retreated to tropic climates.

However from the P/T boundary this strategy was not necessary, was not enough advantage to the returning conservative reptiles; and was difficult to be maintained with the decreasing O_2 concentration.

There was however a way to adapt to the decreasing oxygen level without giving up the higher level of organisation. Oxygen is taken through the "surface" of lungs (which is not a surface but rather a fractal with an index between 2 and 3) and is used in metabolism in the volume of the body with fractal index 3. So one can guess that the halving of oxygen concentration is balanced by more than halving the linear sizes. Of course, shrinking sizes may increase the heat loss, but the environment was hot and insulation by hair developing. For any case the shrinking bodies did not permit to relax the need of endothermy, high metabolism, etc.

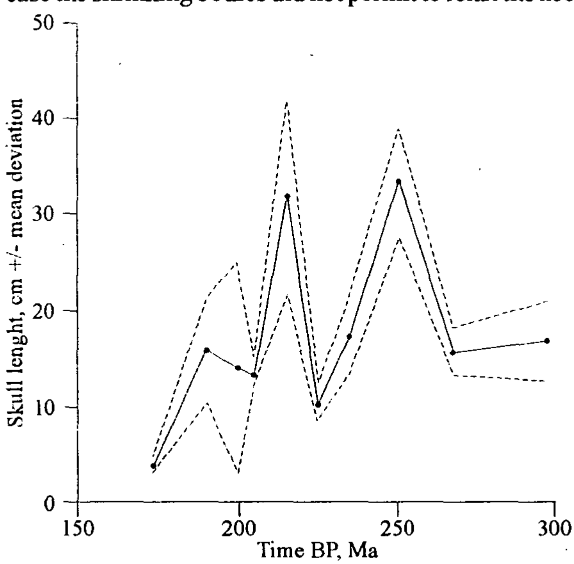

Fig. 5 Average synapsid skull lengths with standard deviations calculated from Figures of Kemp.

Now the shrinking can be seen in fossil data. We used the drawings of *Kemp* (1982), first all of them with complete skeleta. By measuring them it turns out (*Bérczi et al.*, 1997) that, apart from some early pelycosaurs, during the synapsid evolution the ratio of body length (including skull but excluding tail) and skull length is continuously cca. 4, as well for therapsids as for old and recent mammals. Then skull pictures with precise magnification factors can be used as first approximations instead of full bodies. In *Kemp* (1982) we found 6 dozen such figures and *Fig. 5* gives the averages and mean deviations for 10 aggregated times as follows: Upper Carboniferous, Lower Permian, Upper Permian till Tapinoceras horizon, Upper Permian later, the Lystrosaurus level (just after P/T), Lower Triassic after the Lystrosaurus level, Middle Triassic, the Santa Maria formation (from South America), Upper Triassic after the Santa Maria age, and the South Welsh fissures (uppermost Triassic or basal Jurassic) and some other mainly Jurassic skulls. Absolute ages were needed to draw the diagram, but the geologic ages are more reliable; in numbers we took the averages of 2 reliable chronologies in *Farquhar* (1967). The average skull lengths are also shown on *Fig. 1*.

As we see, skulls (so animals) were biggest in the first half of Upper Permian (cold climate and still 0.8 PAL O_2); the maximum skull size in the analysis was 80 cm, corresponding to cca. 320 cm body length. The first serious diminution happened just after the P/T catastrophe. Then first the sizes regenerated but there was another shrinking in Middle Triassic, at the minimum of oxygen level. The final dwarving to Jurassic may have been already the effect of the big concurrent diapsids than that of the environment.

At the same time the low oxygen level was much less problem to the returning diapsids than to the synapsids. Diapsids were not endothermic at that time, so sizes were thermodynamically irrelevant for them. They did not have energy-consuming strategies, not only for heat equilibrium: the gait in the Triassic was generally lizard-like. When the oxygen-concentration went up in the Jurassic, no hard limits existed either for thermal balance or for fast motion: Jurassic mammals were "erect" quadrupeds and some big dinosaurs erect bipeds.

9. CONCLUSIONS

We collected evolutionary advances and their stamps on therapsid reptiles achieved during the Permian-Mesosoic periods and on the basis of their constraints we can conclude the following assertions about Permotriassic climate:

1) In the light of the better documented Pliocene/Pleistocene glaciation the temperature of the Permian glaciation must have been lower than that values estimated by Budyko et al. 1987.

2) In mammalogenesis cold could not have been the only constraint and challenge for therapsid reptiles during late Permian and early Triassic.

3) Further studies and documentations of the P/T boundary events will play important role in clarifying the nature of constraints at the boundary. These studies may also emphasize the roles of both the cosmic event and mammalogenesis in paleoclimatologic reconstructions of the terrestrial atmosphere.

Acknowledgements

The authors would like to thank Drs. Gy. Koppány, I. Molnár, H. Miono and Cs. Detre for illuminating discussions.

REFERENCES

Abraham, Z. and Iben, I., 1971: More Solar Models and Neutrino Fluxes. *Ap. J. 170*, 157-163.

Bérczi, Sz., Holba, Á., Lukács, B. and Papp, É., 1997: Notes on the mammalian evolution. KFKI-1998-12/C. (in press).

Budyko, M. I., Ronov, A. B. and Yanshin, A. L., 1987: *History of Earth's Atmosphere*. Springer, Berlin

Davis, R., Rogers, L. C. and Radeka, V., 1971: *Bull. Amer. Phys. Soc. 16*, 631

Edmeades, R. and Baudinette, R. V., 1975: Energetics of Locomotion in a Monotreme the Echidna Tachyglossus aculeatus. *Experientia 31*, 935-936.

Emiliani, C., 1958: *Sci. Amer. 198*, 54

Erwin, D. H., 1993: *The Great Paleozoic Crisis. Life and Death in the Permian*. Columbia Univ. Press, N. Y.

Farquhar, R. M., 1967: Radioactive Geochronology. In *Runcorn, S. K.* (ed.), *International Dictionary of Geophysics*, Pergamon Press, Oxford.

Fowler, W. A., 1972: What Cooks with Solar Neutrinos? *Nature 238*, 24-26.

Géczy, B., 1996: Extinctions and Astroblemes. *Annales Univ. Sci. Budapestiensis, Sect. Geophysica & Meteorologica 12*, 13-16.

Ishida, K., Yamashita, M. and Ishiga, H., 1992: P/T Boundary in Pelagic Sediments in the Tanba Belt, Southwest Japan. *Geol. Rept. Shimane Univ. 11*, 39-57.

Isozaki, Y., 1994: Superanoxia across the Permian-Triassic Boundary: Record in Accreted Deep-Sea Pelagic Chert in Japan. Canadian Society of Petroleum Geologists. Memoir 17, 805-812

Kemp, T. S., 1982: *Mammal-like Reptiles and the Origin of the Mammals*. Academic Press, London.

Koppány, Gy, 1996: Mutual evolution of terrestrial atmosphere and biosphere. *Acta Climatologica 30*, 31-40.

Novotny, É., 1973: *Introduction to Stellar Atmospheres and Interiors*. Oxford University Press, Oxford.

Schwarzschild, M., 1958: *Structure and Evolution of Stars*. Princeton University Press, Princeton.

Tóth, I. et al., 1997: A Possible Nearby Supernova Explosion in the Permo-Triassic Boundary &c. TISS, ed. by Miura, Y. et al., Yamaguchi University, pp. 18-19.

Woldstedt, P., 1969: *Quarter*. Encke, Stuttgart.

Készítette a JATEPress
6722 Szeged, Petőfi Sándor sugárút 30—34.
Felelős kiadó: Dr. Keveiné dr. Bárány Ilona docens, tanszékvezető
Felelős vezető: Szőnyi Etelka kiadói főszerkesztő
Méret: B/5, példányszám: 300, munkaszám: 111/1998.